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THE LAURENTIAN PENEPLAIN.

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INTRODUCTION.

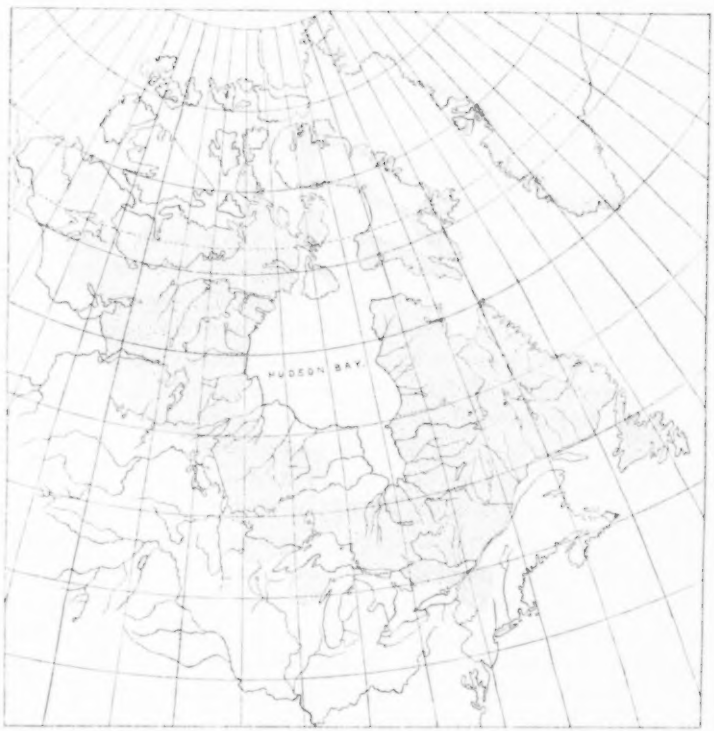
THE late director of the Geological Survey of Canada, Dr. George M. Dawson, in his address before the Geological Section

of the British Association, at the Toronto meeting in 1897, mentioned, in passing, that the topographic features of the Archæan areas of North America were those of a peneplain. During the past seven summers the writer has had the opportunity of studying in more or less detail considerable areas around the southern portion of this Archæan region extending from Lake Champlain in the east to the Hudson Bay divide in central Keewatin. In a paper published two years ago (41)[1] attention was drawn to some of the geographic features of the southern margin of the Archæan belt within central Ontario. In the present paper, with the aid of the numerous accounts of travels and reports of explorations in various parts of these Archæan regions, these studies have been extended to the greater areas of central and eastern Canada

The purpose of the present paper is, primarily, to draw attention to the physiographic unit, the Laurentian Peneplain,[2] and to present a brief picture of its more salient features; and, secondly, to outline a few of the almost endless variety of geologic and geographic problems which the Canadian shield presents. Many of these problems, in the present state of our knowledge of the vast area here under discussion, are insolvable; many perhaps will never be solved; but none the less it is interesting to review the work already done and to consider that which lies before us.

[1] The number refers to the article listed with corresponding number at the end of this paper. A following number indicates the page reference to the article in question.

[2] The adjective "Laurentian" is here applied to this, the largest peneplain developed in Canada, to distinguish this topographic unit from others of a similar type also found in Canada or in the adjacent parts of the United States. For example, we have the Atlantic Coast Peneplain, parts of which, under the title of the New England Peneplain, and the Acadian Peneplain have been described by Davis and Daly respectively; the Tertiary Peneplain of British Columbia has been briefly referred to by Dr. Dawson, and the Peneplain of the Yukon basin has recently been described by H. C. SPENCER, *G. S. A.*, May, 1903. The relations of these minor plains to the greater area here under discussion are not yet definitely established. As will be shown in the succeeding paragraphs, the Laurentian Peneplain itself is not a single plain, but rather is made up of a series of facets intersecting at very low angles, three of which are distinguishable south of the main divide, so that there are probably at least five facets, and perhaps more. It has not been deemed advisable at present to suggest names for these facets.



Sketch map to show the area included by the Laurentian Peneplain. The peneplain area is shaded.

It is not proposed in the present paper to enter upon any discussion of the strictly geologic problems offered by the rocks of the area—such as a consideration of the stratigraphy, origin, and relations of the metamorphic and igneous rocks of the great Archæan complex.

THE CANADIAN OLDLAND.

In its general features eastern North America presents in a most striking manner and on a large scale what may be regarded as a typical development of physiographic forms characteristic of a belted ancient coastal plain centered around an oldland area. The Canadian shield of Suess, the area whose general physiographic features are to be more particularly described and discussed in the succeeding pages of this paper, marks the site of the oldland area from which the materials of the later sedimentary deposits were derived. A reference to the accompanying sketch map (inset) will show the general U form of this oldland area, which extends from Coronation Gulf in the extreme northwest, southward around Hudson Bay and northward through Labrador to Baffin Land and beyond. Its width varies from nearly a thousand miles in Labrador to about two hundred miles in the country southwest of James Bay.

Bordering the oldland on its convex side, and extending from the island of Anticosti in the Gulf of the St. Lawrence westward and northward as far as the Arctic circle, and probably beyond, we have a series of land forms presenting on the grandest scale the general features of an ancient belted coastal plain, in its present aspect much modified, it is true, from normal form —a modification probably due to the operation of relatively recent processes, differential uplift, and glacial action. The belted coastal-plain features are best preserved in the region of the Great Lakes. The most prominent topographic feature of this costal plain is the Niagara cuesta, which can be traced with varying expression from near Rochester, on the south shore of Lake Ontario, westward as far as the state of Wisconsin, beyond which it disappears for a time beneath the drift, but reappears to the west of Lake Winnipeg. Lakes Erie, Huron, Michigan, Manitoba, and Winnipegosis are situated upon the outer lowland;

Lake Ontario, Georgian Bay, Green Bay, and Lake Winnipeg lie upon the inner lowland in front of the cuesta. Lake Superior lies in a depression away from both lowland and cuesta. The portion of the ancient coastal plain in the vicinity of the Great

FIG. 1.—Sketch map of the Laurentian Peneplain and the country adjacent—west and southwest of Hudson Bay.

Lakes presents in general aspect and in its present attitude the normal features of such a plain, with numerous drainage modifications due largely to differential uplift and glacial ice action. The portion of the plain which lies west of the oldland area is at

present in such an attitude that practically all the streams flow against the dip of the rocks—a direction opposite to that normally found on a belted coastal plain—a modification in this case apparently due to the uplift of the Cordilleran system on the west.

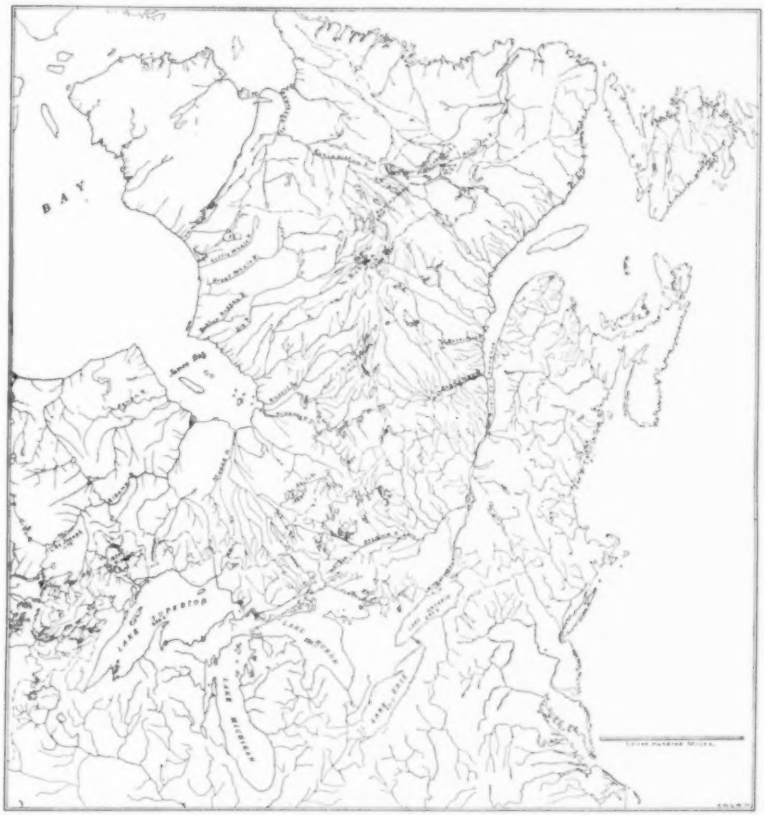


FIG. 1.—Sketch map of the Laurentian Peneplain and the country adjacent—south, southeast, and east of Hudson Bay.

On the southeast side of the oldland the valley of the St. Lawrence lies on a lowland cut on Paleozoic sediments, and shows at the extreme west in the valley of the Ottawa River, and at the east in the Mingan Islands and the Island of Anticosti,

typical cuestas with inner and outer lowlands. In the central parts, in the vicinity of Montreal, the relation of the plain to the oldland areas, which stand boldly above it on either side, suggests that here the Paleozoic sediments may have been deposited in a pre-Paleozoic depression of the graben type. The well-known Monteregian hills, the stubs of post-Devonian volcanoes, form prominent buttes rising to a considerable elevation above the level of the St. Lawrence lowland.

On the concave side of the oldland area we find traces of an ancient belted coastal plain, convex southward, but for the most part its features are buried beneath the deposits which form the recent Hudson Bay coastal plain.

EXPLORATION AND SURVEYS.

The Laurentian Peneplain extends through about fifty-eight degrees of longitude and about twenty-three degrees of latitude, covering in all an area of over two million square miles. During the ten centuries that have elapsed since the first daring Norse mariner landed on its eastern shore, many explorers have traveled along the margins of the area, and not a few have traversed it in diverse directions. The early explorers, repelled by the bold and forbidding coast formed by the eastern edge of the uplifted peneplain, along the northwest shore of the Gulf and River St. Lawrence, chose rather the easy route offered by the free navigation of the great river, and penetrated to the heart of the continent and to the more inviting areas lying to the south of the great Archæan belt, long before traverses were made across the peneplain itself. At a later period the active searches instituted to discover a short route to China led to the discovery of Hudson Bay. The continued search for the northwest passage and the attractions offered by the profits of the fur trade resulted in the exploration of portions of the coasts of this inland sea, and in the establishment on its shores, more than two hundred years ago, of trading posts, some of which are still in existence at the present day. In the interests of the fur trade many traverses of the district were made by the employees of the great trading companies, both northward from the early French settle-

ments and southward and westward from the English posts on Hudson Bay. Records of some of these exploratory journeys and records of the travels of the Jesuit missionaries are still extant. Later explorations, incident to the continued search for a northwest passage from Hudson Bay, led several parties across the far northwest portion of the area. Until quite recently the imperfect records of these travelers constituted the only available accounts of large areas of the interior.

The period of active geographic and geologic investigation of this region really began about fifty years ago with Logan's historic work on the geology of the Archæan districts north of the Ottawa River. Since that time more or less systematic geographic and geologic explorations have been carried on, chiefly by the Geological Survey of Canada, but in part by the Topographic Survey's branch of the Department of the Interior at Ottawa. At present we have at least a general knowledge of the main geographic features of the Laurentian Peneplain, although much still remains to be done.

The information used in the present paper, outside that from the writer's personal observations, has been derived chiefly from the reports of the explorations of A. P. Low in Labrador, of Dr. Robert Bell and Dr. A. E. Barlow in the districts to the south and southwest of James Bay, and of J. B. Tyrrell, and J. W. Tyrrell in the country to the east of Hudson Bay. In the papers by A. P. Low, J. B. Tyrrell, J. W. Tyrrell, and Dr. George M. Dawson, to which reference is made below, nearly complete bibliographies will be found dealing with the literature of the subject. It does not seem necessary to reproduce the bibliography here.

The writer is indebted to Mr. A. P. Low, of the Geological Survey Department, Ottawa, for some suggestions to which due reference is made in the text, and also for a number of photographs from central Labrador, from which Figs. 2, 3, 4, 5 and 13 were prepared. He wishes also to acknowledge his indebtedness to Dr. F. D. Adams, of McGill University, Montreal, and to Bailey Willis, of the U. S. Geological Survey, for critical readings of portions of the manuscript of this paper. To Dr.

Adams also the author is indebted for the photographs from which Figs. 6, 7 and 8 were prepared. He has also to acknowledge the kindness of Mr. James A. Smart, deputy minister of the interior, from whom the photographs to prepare Figs. 9, 10, 11, and 12 were obtained.

The original photographs from which the figures were made are deposited in the Collection of Geological Photographs of McGill University, Montreal.

PHYSIOGRAPHIC CONTROLS.

One of the most interesting problems for study presented by the Laurentian Peneplain is the control which the type of topography here developed has had upon the occupation and exploration of the region. Stretching, as it does, from the frozen Arctic to the temperate regions of central Ontario, and from the ocean border on the east to the mid-continental region of the great plains on the west, in its different parts it presents many phases of the operation of climatic controls, which affect its flora, its fauna, and its human occupation.

The uplands of Labrador and the far northwest of the region (north Keewatin, and northeast Mackenzie) are devoid of trees, the vegetation being confined to the lower orders of plants. Next southward we find the belt of conifers stretching all across the region from Hamilton Inlet to northwest of Great Slave Lake, the trees increasing in size and variety with decrease of latitude. In the central parts deciduous trees abound. Although, in general, throughout the region we find uniformity of features, in structure and development there is a great diversity of detail. The enormous number of the lakes and streams, the widespread distribution of the forests, the general uniformity of the topography, and the climatic characteristics of the region, have all contributed to make it the home of those animals whose flesh is valuable for food, and whose pelts are valuable for clothing or (secondarily) as an article of commerce. The remarkably even character of the region, the character of the flora, and the protection offered by climatic conditions even now make possible the existence of those vast herds of caribou (comparable to the

herds of buffalo which roamed the great plains of the West until after the advent of the destructive white man) which at present roam over the barren grounds (see Fig. 8). The character of the country makes the continued existence of the fur-bearing and game animals possible. The widespread distribution of these animals, the chief support of the inhabitants, has led to the scattering of the people over the whole area, and to the development of more or less nomadic habits and customs.

The Indian inhabitants of the region, living chiefly on the products of the chase, have here, from time immemorial, found their hunting-grounds. The numerous lakes and streams, then as now, were the only lines of communication in all that vast area. Their distribution through all parts of it, and the comparative ease with which traverses from one body of water to the next can be made, enabled these people to wander unimpeded over the whole region. The customs of these people, in the several parts of the area, differ but little; in language there are greater differences, but over very large areas the speech is the same. Probably nowhere else, over so large an area, have scattered communities been found which have retained so well their communal characteristics. In language, customs, and culture they differ greatly from the various tribes found in the mountainous districts of British Columbia. In some of the still unexplored parts of the region there are Indians who have never yet seen a white man, unless perhaps some half-breed trader.

On the other hand, to the average white man, with his different modes of living, the region with its exceedingly limited agricultural possibilities, has always been inhospitable. He has displaced the Indian in the fertile plain regions which border the peneplain area to the south and west. The last remnants of some of these displaced tribes still survive upon these uplands, and still eke out a more or less precarious existence on the products of the chase. To the white man, however, the region offers other inducements which lead to the temporary occupation of local areas. The degradation which produced the peneplain has not only made possible the widespread forests, but has also exposed valuable mineral deposits that otherwise would not have been

accessible. The region is thus of the utmost importance as the source of almost a world's supply of timber, and of the products of the mine, more particularly iron ore.

The journeys of the early explorers across the region were possible because of the character of its topographic features. They were undertaken by the early missionaries almost always, and by the fur-traders, frequently, to visit the wandering Indians scattered throughout the region. The fur-traders often undertook journeys solely for the pupose of hunting. The stories of the travels of these early missionaries as told by Parkman and others, and the history of the great fur companies, incidents of which form the historic foundation of many tales, afford some of the most fascinating chapters in the history of Canada, and in the study of the physiographic controls of this region. The early exploration of the eastern, central, and southern part of the western arm of the area were largely made by the early Jesuit missionaries and the employees of the great trading companies. The exploration of the far northwest, on the other hand, with the exception of three years' adventurous wanderings of Hearne, an employee of the Hudson Bay Company, were merely incidental to the continued search for a possible northwest passage.

The climatic conditions of the far northwest; and the absence of soil in any considerable amount from the Labrador areas and the country just north and west of Lake Superior, means that these regions will always be shunned by the majority of white men in search of a permanent abode. There are, however, considerable areas where there is a good soil cover, generally of fine glacial or lacustrine clays and sands, which are habitable and lie within the wheat belt. The largest of these lies between James Bay and the Lake Superior divide. Smaller areas, now partly occupied, occur in the vicinity of Lakes Temiscaming and St. John. The region is, however, one of great promise in another respect. Under progressive governmental control, and the competent supervision of trained forest engineers, it could be made an immense permanent forest reserve, a source of timber for many centuries to come. At present the timber resources are being rapidly exhausted, and practically no provision is made for the restoration of the forests.

Until the work of scientific exploration was undertaken by the government, little valuable information about the resources of the area was available, although much had been gathered in the preceding two hundred years by the employees of the great trading companies. This information was, however, kept buried in their archives, since the policy of these companies required that the richness and extent of their domain be kept secret as much as possible.

The beauty and diversity of the scenery, the innumerable lakes and waterways, the fascination of the dense forests, the salubrity of the upland climate during the summer season, and the opportunities afforded for exercising the innate hunting instincts present in nearly every man, will more and more make the accessible portions of the region the resort of those who would for a time leave the tiring, nerve-straining experiences of our modern cities behind them and find quiet, rest, and health in the peaceful wilds of the Laurentian Peneplain of Canada.

THE DATE OF EMERGENCE OF THE CANADIAN SHIELD.

The earlier studies of Walcott (39) on the Cambrian, and the recent investigations of Ulrich and Schuchert on the later Paleozoic, faunas of North America have led to the conclusion that

> the present North American continent was in existence and practically in full development as land at the close of Algonkian time, and that since that period, the Canadian shield and other smaller Archean land areas have never been wholly submerged. The periodic encroachment of the sea on the Canadian shield attained considerable extent on the north and west and more particularly on the south. The east shore, on the contrary, remained nearly the same till comparatively recent time—probably Post-cretaceous. (37, p. 659.)

Accepting these conclusions, it would naturally follow that a land area exposed for so long a time as has since elapsed would have undergone extreme degradation, and we should naturally expect to find it exhibiting all the features characteristic of the penultimate stages of the geographic cycle.

On the other hand, if we investigate the features of the region under discussion, we are led to similar conclusions. The very

even surface of the area, in almost every part from Labrador south around Hudson Bay to the Arctic Ocean, is found to truncate the structure of intensely metamorphosed igneous and sedimentary rocks, irrespective of their hardness or attitude. The metamorphism is such as to imply that they have been at one time buried deeply beneath the surface of an overlying land mass, and have been subjected to the strains and stresses of intense orogenic movements. The removal of overlying mass of rock must have occupied an immense interval of time. How great it is impossible to say. For part of the area at least, this degradation took place before late Paleozoic time, for we find Paleozoic sediments resting upon a modified peneplain surface. It seems probable that for the central portions the interval was much longer.[1]

In brief, a study of the physiographic features of the Laurentian Peneplain must undoubtedly lead to the conclusion that the Canadian shield has been, for an exceedingly long interval of time exposed to processes of erosion which were chiefly subaërial; and a study of the relations of the central peneplain surface to the surface upon which the Paleozoic sediments around the margin rest shows that at least parts of the peneplain were produced before later Paleozoic times. It is only by stratigraphic studies, however, that approximate dates can be assigned for the origin of specific features.

FEATURES OF THE PLANATION SURFACE.

1. *Character of the sky-line.*—The most dominant and striking feature of the whole region, from the northern part of the interior of Labrador following approximately the median line of the region around to the south of James Bay and northwest toward the Arctic Ocean, is the remarkably even character of the sky-line. With few exceptions, to be noted elsewhere, almost everywhere in the interior it is found that from any slight elevation, which lifts the observer above the tree line, the bounding horizon is very even and almost circular. The many traverses

[1] It must be noted in this connection that Lawson, writing in 1888, dissents from the view that the Archæan rocks were ever elevated into mountains (18, p. 23).

which have been made across the different parts of the area show, particularly for the western portion of the peneplain between the Great Lakes and the Arctic Ocean, that for many miles the greatest elevation is often not over fifty feet higher than the

FIG. 2.—East coast of Hudson Bay, six miles up the Povungnituk River. Elevation 50', looking inland.

(*Photograph by A. P. Low, 1899.*)

adjacent lowest depression, and as a rule the actual surface may be described as gently undulating. Occasionally the measure of relief may equal one hundred feet, but, particularly in the western arm of the peneplain, elevations of this amount are prominent

FIG. 3.—East side of Hudson Bay, thirty miles up Sorehead River. Elevation about 150', looking inland.

(*Photograph by A. P. Low, 1899.*)

landmarks, visible for many miles, and from a distance are frequently seen to stand above the even sky-line of the adjacent regions, so that they may more properly be classed as monadnocks. In the country to the south of James Bay the measure of relief is somewhat greater, but the even sky-line, occasionally intercepted by residuals, is still the dominant topographic feature. In the eastern portion of the peneplain for long dis-

tances in the central parts the surface is practically the same as on the western half. Toward the margins it is more rugged or uneven, while toward the extreme northeast, close to the Atlantic coast, there is a narrow range of mountains rising prominently above the peneplain surface.

When the character of the surface is considered more in detail, it is found that, except for some very small areas, and in places where the peneplain surface is buried beneath the much younger glacial and alluvial deposits, the surface is nowhere quite flat, but is covered with low, rounded domes and ridges, which are roughly parallel to themselves and whose longer axes conform in general to the strike of the rocks.

The remarkably even character of the sky-line together with the universal distribution of many large and small lakes at levels little below that of the even sky-line, justifies the assumption that differences of elevation between different water bodies in the depressions upon the surface of the plain represent closely the differences in elevation between portions of the peneplain adjacent to each of these water bodies respectively. On this basis it will be found that the average gradient varies in different parts from one to about four feet per mile. For example, between Selwyn Lake (1,340′) and Doobaunt Lake (500′), along the line of the Doobaunt River, west of Hudson Bay, the average gradient is 2.8 feet per mile for a distance of approximately 300 miles. A section eastward from Cree Lake (1,530′) to the junction of the Churchill and Little Churchill Rivers shows an average gradient of 1.8 feet per mile for 450 miles. A study of the profiles of the Canadian Pacific Railway between Montreal and Winnipeg, where the line runs over the upland, shows between Buda (1,472′) and Brulé (1,355′) a fall of 117 feet in a distance of 146 miles; between Cartier (1,398′) and Lac Poulin (1,504′) the rising gradient is 106 feet in a distance of 129 miles. In central Labrador a section between Lake Nichikun (1,760′) and Lake Kaniapiskau (1,850′), and thence to Lobstick Lake (1,630′) above the Grand Falls on the Hamilton River, shows an ascending gradient of 90 feet in the first 100 miles, and then a descent of 220 feet in 200 miles, or a mean

gradient of approximately a foot per mile. In a direction along the divide (1,550′) from southeast of Lake Mistassinni to Lake Kaniapiskau (1,850′) the rising gradient is almost exactly one foot per mile.

By way of comparison, from the profiles of the Canadian Pacific Railway between Winnipeg (757′) and Calgary (3,428′) in the foothills of the Rockies, the gradient is found to be 3.18 feet per mile. Between Edmonton (2,407′) and East Selkirk (744′), along the old location line, *via* the Yellowhead Pass, the gradient is 2.1 feet per mile. In each of the above cases, if shorter sections are taken on each of the three prairie steps, it will be found that for each step the gradient across the plains is much less than the figures here given.[1]

The comparison of the two gradients across the great plains with the gradients upon the peneplain surface, taken in conjunction with the character of the sky-lines in the two areas, shows the appropriateness of the term "peneplain" as a term to describe the principal geographic feature of this topographic unit.

2. *Departures from the normal peneplain type.*—On an area reduced to a peneplain one would expect to find a gently undulating surface, with the larger streams meandering in broadly open valleys. Their power to erode would long before have begun gradually to diminish, in part by reason of the lessened rainfall due to the reduced elevation above sea-level, in part because of the reduced grade. Their sluggish character, diminished water-supply, and low velocity will not enable them to transport the waste of the land except in a very fine state of division, or in solution. Hence the surface of a normal peneplain would be composed of mantle rock of considerable depth, at the surface very fine in texture, and gradually changing with depth to unaltered bed rock. A very even surface, deep soils, and streams which have long before lost the adjustments of early maturity, the absence of lakes, and an elevation little above sea-level must be characteristic features of a land area which has been reduced

[1] In the profiles taken along the lines of river valleys it is to be noted that the distances are estimated in straight lines, not along the stream courses. It will be found that the average gradient of the stream course is much less.

to the peneplain condition by the processes of subaërial degradation.

We have already seen that the Laurentian peneplain exhibits to a most marked degree the even sky-line and low surface gradients. We find, however, that it is almost devoid of mantle rock *in situ*. That which occurs, with the exception of an exceedingly small amount, almost too small to notice, was brought to its present location by glacial or aqueous processes of transportation. The drainage over most parts of the area is not well established; rapids and waterfalls are the most characteristic features of all the streams. The entire surface of the country is dotted with lakes, which are practically numberless; in places their area approaches 25 per cent. of the whole. And finally, parts of the peneplain are not now in accordant position with respect to sea-level. Thus, although the complicated and contorted rocks of the region are everywhere truncated by a surface which presents a remarkably even sky-line, in almost every other respect the features of the region are different from those characteristic of a peneplain. Since the production of the peneplain surface which traverses the rocks of the region, the surface of the plain has undergone profound modification, leading to the production of the present features.

In the descriptions which follow, the general nature of these departures from the normal type of peneplain will be described more in detail, and at the end of the paper a brief reference will be made to the processes which may have brought about these modifications. In general it may be said that the present attitude of different parts of the plain with respect to sea-level is due to a differential uplift, which, in parts of the area at least, is still going on. The later dissection of the plain, the carving of deep, broad valleys or of narrow canyons, seems to be a function of this uplift, though many of the first class of depressions here mentioned may antedate the peneplain. The absence of mantle rock *in situ*, the occurrence of the numerous lake basins, and the inmaturity of the drainage systems are usually attributed to the erosive action of glacial ice.

3. *Detailed descriptions of characteristic portions of the plain.*—

In the present attitude of the peneplain the highest part is found in central Labrador, where, to the south of Lake Nichikun, it reaches an elevation of approximately 2,400 feet above sea-level. The plain slopes outward from central Labrador toward Hudson Bay and the Gulf of St. Lawrence, the margins of the plain proper, near the coasts, being at considerable elevations.

In his report on explorations in James Bay and in the country east of Hudson Bay, drained by the Big, Great Whale, and Clearwater Rivers, Low describes the interior of this part of the peneplain as a

> rough table-land having an elevation of about 700 feet above sea-level near its edge, and slowly rising inland to over 2,000 feet at its highest. The edge of this table-land leaves the coast to the north of Cape Jones, and runs in a S. S. E. direction, so that to the southward there is an interval varying from ten to thirty miles between it and the coast. In this portion the general level is not much over 100 feet above the sea, and the soil is of Post-Pliocene clays and sands, with alluvium. . . . . The land is rolling and broken by low rocky Archæan hills, which make up about one third of the entire area. (23, p. 16).

The same writer describes the area of country stretching from the Gulf of St. Lawrence northwestward to Hudson Bay as

> a low-lying plateau of Archæan rocks. The height of this plateau averages about 1,500 ft. above sea-level, and rising slowly from about 1,000 ft. near the edge to about 2,000 ft. in the interior. The surface of this plateau is by no means flat, being covered by the low rounded hills, which are roughly arranged in a series of ridges more or less parallel to themselves and the general strike of the rocks. These hills are the stubs of extensive and elevated mountain chains which, from exposure to subaërial denudation, for countless ages, and from having been subjected to glacial action of later geological times, have been ground down to their present unimposing state. In the interior the difference of level between these ridges and the valleys separating them is small, the hills seldom rising 100 ft. above the general level. As the coast is approached the difference is more marked, the long action of ancient rivers having deeply cut out the principal valleys below the surrounding country, thus causing a more marked contrast in level, and at the same time much finer scenery. (24, p. 14.)

Summing up the statement of a series of levels in different parts of the Labrador area Low writes:

> The interior of the peninsula is almost flat, so that in an area of 200,000 square miles, there is not a difference of general level of more than 300 or

400 feet, and the highest general level of the interior is under 2,500 feet. A belt of land somewhat higher than the general interior follows the St. Lawrence coast, a short distance inland. The northern half of the Atlantic coast rises in a chain of mountains considerably higher than any other portion of the peninsula. Along the northern and western coasts there is no evidence yet obtained to show the existence of a coastal ridge, but rather a probability that the general elevation increases towards the interior. (24 p., 23.)

FIG. 4.—Interior of Labrador, country north of Lake Michikaman.
(*Photograph by A. P. Low, 1894.*)

The divide between Hudson Bay drainage and that flowing into the St. Lawrence lies almost midway between the two water bodies. Throughout the greater part of its course the divide is frequently not well defined; at times it is well marked. Low describes it in the vicinity of Lake Mistassinni as a ridge of hills

FIG. 5.—View of the country on the Hamilton River, about fifty miles above Grand Falls, showing the character of the interior plateau.
(*Photograph by A. P. Low, 1894.*)

forming an escarpment about 300 feet high. Elsewhere he mentions that this divide is a prominent topographic feature for over fifty miles.

The St. Lawrence portion of the Labrador division of the uplifted peneplain does not slope uniformly from the interior divide toward the gulf. On the contrary, there seems to be, as

it were, a sag in the surface of the peneplain between these two locations. The margin of the plain parallel and close to the St. Lawrence River, in the vicinity of the outlet of the Saguenay River, reaches an elevation of over 1,500 feet, and there is a well-defined gentle swell, whose height approximates to this elevation

FIG. 6.—Looking across Lake St. John from the discharge of the Saguenay, the margin of the upland makes the even sky-line in the background.

(*Photograph by Dr. F. D. Adams, 1884.*)

extending from southwest of the Saguenay in the neighborhood of Quebec, for a considerable distance along the southeast margin of the plain to below the St. John River. Between this swell and the interior main divide is a gentle depression. The lowest part of this depression forms the well-defined basin of

FIG. 7.—Central Ontario. The upland shows the less even sky-line of one of the pre-Paleozoic facets.

(*Photograph by Dr. A. E. Barlow, 1898.*)

(This photograph will accompany a detailed report on the geology of this area by Dr. F. D. Adams and Dr. A. E. Barlow.)

Lake St. John (314′), in this particular case probably located on a graben block. The majority of the streams rising near the interior divide are found to cross this marginal swell in the peneplain through deeply cut, steep sided gorges or canyons.

The best known, broadest, and deepest of these is the gorge of the Saguenay, a true fiord.

From the vicinity of Quebec westward to Lake Superior, and thence northward *via* Lake Winnipeg, Lake Athabasca, and Great Slave Lake, the convex margin of the peneplain is bordered by ancient sediments, Paleozoic for the most part; but in the extreme northwest Cretaceous deposits are found resting upon its surface. The inner or concave side of the peneplain to the south and west of James Bay, and extending as far north as Fort Churchill, is bounded by a narrow belt of Paleozoic sediments. North of Fort Churchill the ancient peneplain merges gradually with the modern coastal plain of Hudson Bay. The northern end of the western arm of the plain probably passes beneath Paleozoic sediments known to occur north of the Arctic circle. The surface of the peneplain north of the main divide and south of the lower waters of the Albany River and of James Bay, particularly that portion drained by the Moose River system, is almost completely buried beneath clays and sands, chiefly of glacial origin.

The divide on that part of the ancient peneplain south of James Bay lies nearly midway between the northern and southern boundaries of the plain, north of the city of Ottawa. From the vicinity of Lake Abitibi it runs westerly toward the most northern point of Lake Superior, so that in the longitude of Schreiber station, on the main line of the Canadian Pacific Railway, it lies not more than twenty-five miles north of the lake. From here it swings to the northwest, passing to the north of Lake Nipigon, and thence turns southwest toward Savanne on the Canadian Pacific, and continues southward, crossing the international boundary. A portion of the Archæan region lies to the south of the boundary in the states of Michigan and Minnesota, and portions of this area drain into Lake Superior. Following along the line of the western margin of the peneplain, however, from the international boundary as far north as Methy portage (lat. 56° 40′ N.; long. 109° 55′ W.) the main divide lies west of the peneplain and at the summit of the Rocky Mountain range. A subdivide, a little to the east of Lake Win-

nipeg, and on the peneplain, separates the headwaters of a few short, westerly flowing streams from the waters of streams flowing to Hudson Bay. All the waters from the river systems whose chief streams are the English, Red, Assiniboine, and Saskatchewan

FIG. 8.—Caribou on the banks of the Doobaunt River, Keewatin District.
(*Photograph by J. B. Tyrrell, July 30, 1893.*)

FIG. 9.—Great Slave Lake, looking north from Fort Smith.
(*Photograph by J. W. Tyrrell, 1900.*)

Rivers reach Lake Winnipeg (710′) just on the margin of the plain, and thence cross the plain in a broad shallow depression, *via* the Nelson River to Hudson Bay. North of the Nelson the Churchill River system also drains a considerable portion of the central plains across the ancient peneplain. Still farther north

the main divide is again located on the peneplain, separating the Mackenzie River system from a number of river systems whose main direction of flow is a little to the east of north for nearly half their courses, and then eastward in broad, open valleys toward Hudson Bay.

It has already been noted that in central Labrador the main divide has a highest elevation of about 2,400 feet. South of James Bay the elevation of the main divide on the peneplain is about 1,400 feet above sea-level, as a maximum; in places it is somewhat lower. North of Schreiber it has an elevation of about 1,345 feet. East of Lake Winnipeg (710′) the sub-divide at the headwaters of the Berens River stands at about 1,400 feet above the sea. In the interior, north of the Churchill River, the elevation in places exceeds 1,600 feet. The divide north of Lake Athabasca stands at an elevation of about 1,400 feet.

Dr. A. E. Barlow, in his report on the Nipissing and Temiscaming map sheets, thus describes the topography of a portion of the central part of the peneplain to the south of James Bay:

> The general character of the country may perhaps be best described as that of an uneven or undulating rocky plateau, with a gentle slope toward the east and southeast. Although in detail the surface of this plateau is far from uniform, consisting of a succession of more or less parallel rocky ridges, with intervening valleys occupied by swamps or lakes, still the district as a whole has a general elevation varying from 900 to 1,200 feet above the sea. There are no very prominent hills, the highest seldom attaining a greater altitude than 300 feet above the surrounding region, while throughout most of the district, hills of 50 to 100 feet in height are rather conspicuous topographical features. The highest land in the whole area is situated near the northwest corner of the Temiscaming sheet, immediately to the west of Lady Evelyn (Mus-ka-na-ning) Lake, where a range of hills, of which Maple Mountain is the highest peak, rises to the height of a little over 2,000 feet above the sea, according to Dr. Bell.
>
> The influence exerted by the underlying rock on the general contour of the surface, is perhaps nowhere better exemplified than in the region embraced in this report. In the southern and southeastern portions, where the prevailing rocks are the various gneisses and granites included as Laurentian, there are no hills of any great height, the general surface presenting, as usual, a rather monotonous succession of low rounded hills, with corresponding shallow rocky valleys. In the northern and western portion, however, those areas in which the quartzites are present, as well as those in which the

plutonic rocks, chiefly granite and diabase, are prevalent, rise into rather important elevations; while those regions which are underlain by the slaty member of the Huronian, are on the other hand low and flat. A remarkable resemblance exists between the contour of the surface, occasioned by the presence of the diabase rocks, and that produced by the heavy-bedded and massive quartzite, that forms the highest member of the Huronian exposed in this district, both rising into comparatively high rounded or broken ridges and rendering the stretches of country where such rocks prevail, exceedingly rough and hilly. . . . . This rough and broken contour is in marked contrast to the flat surface characteristic of the region in which the slates obtain. (4 p. 21.)

McOuat also draws attention to the general level character of the country south of Lake Abitibi, and mentions the occurrence of two remarkable hills which rise more than 700 feet above the general level. Lawson in his report on the Rainy Lake country also draws attention to the generally even character of the surface, and mentions the striking contrast offered by several ridges which rise prominently above the generally even surface. (19, p. 11.)

Farther northwest, near Lake Winnipeg we find "The country near the river (Berens) . . . . is made up of many low hummocky, gneiss hills, which seldom rise twenty feet above the water, and are partly covered with a heavy clay soil" (Low, 21, p. 5). Nearer the sub-divide we find "The surrounding country is a vast, level swamp, broken only by a few knobs of gneiss, that rise from ten to fifty feet above the general surface" (21, p. 11).

Bell, describing the country along the upper Albany, also draws attention to the generally level character of the district (7, p. 18). J. B. Tyrrell's description of the physical features of the district along the line of the Doobaunt, Kazan, and Ferguson Rivers is as follows:

The general relief of the whole country is very low and unpronounced, much of it having the appearance of vast undulating plains underlain by sandy or stony till and covered with stunted spruce and larch or short grass and deciduous northern plants. Here and there rise rounded rocky hills, the highest of which in the neighborhood of Kasba Lake have altitudes of about 1,700 feet above sea-level. Northeast of Doobaunt Lake some prominent hills of green trap and red conglomerate form conspicuous features in the

otherwise monotonous landscape. From Kasba and Daly lakes the country has a general and moderately regular slope northeastward until it reaches the highest raised beaches or post-glacial shore lines, after which the slope is more directly eastward toward the present shore of Hudson Bay. (34, p. 158.)

Elsewhere he writes:

The northeastern part of this region is underlain by crumpled and distorted Archæan rocks, whose surface has, even in pre-Cambrian times, been reduced to an undulating plain, with very slightly accentuated contours. (35, p. 148.)

FIG. 10.—Sifton Lake and Cairn on Musk Ox Hill, District of Mackenzie. (*Photograph by J. W. Tyrrell, 1900.*)

Again, in a note on the Pleistocene of the Northwest Territories of Canada, Tyrrell writes:

In general physical features the "Barren Lands" often closely resemble the great plains west of Manitoba along the line of the Canadian Pacific Railway, being undulating grass-covered country, underlain by till more or less thickly studded with boulders; but a hard granite knoll projecting here and there serves to remind one that the till is not here resting on soft Cretaceous shales and sandstones and at once accounts for the much greater abundance of boulders. In some places the surface is composed entirely of large subangular boulders, without any matrix of sand or clay, while the shores of Chesterfield Inlet, and part of the northwest coast of Hudson Bay, are bold and rocky. (33, p. 395.)

4. *Drainage features.*—A feature characteristic of the present drainage of the peneplain everywhere from Labrador to northern Keewatin and Mackenzie is that the upper courses of all the riv-

ers upon the plain consist of a series of chains of large and small shallow lakes occupying basins which are generally rock-bound, less often drift-blocked, and which spill over their lowest edge in a more or less ill-defined, sometimes braided stream, characterized by a succession of rapids or falls, to the next lowest

FIG. 11.—Junction of the Thelon and Hanbury Rivers, District of Mackenzie. (*Photograph by J. W. Tyrrell, 1900.*)

basin. The lower courses of the streams flowing across the Hudson Bay coastal plain are generally well defined, the streams lying in valleys incised beneath the surface level of the coastal plain and drift deposits.

In the Labrador area the main streams in their upper courses

FIG. 12.—View on the Upper Thelon River from Cairn Hill, District of Mackenzie. (*Photograph by J. W. Tyrrell, 1900.*)

upon the surface of the plain belong to the general type of streams upon the upland. When they approach the margin of the plain, however, they are found to occupy well-defined, often gorge-like valleys incised in the Archæan rocks of the plateau, often to a considerable depth beneath its surface. As a consequence of this, it is found that the lower courses of almost all the streams entering Hudson Bay on the east are characterized by a long series of falls and rapids, and are impassable by canoes, thus necessitating long portages when it is desired to

reach the interior. This is equally true of most of the streams flowing outward from the interior of the plateau to the Gulf of St. Lawrence, to the Atlantic, and to Hudson Bay. The streams that flow southeast into the St. Lawrence River and Gulf all cross the St. Lawrence swell, before described, in deep gorges incised to a depth of several hundred, and in places more than one thousand, feet below the level of the plain.

Low states:

> The rivers entering James' Bay from the east for their entire length, pass, so far as known, through Archæan country, and consequently present physical characters somewhat different from those on the west side. On their headwaters they flow on the general level of the country and are nothing but a succession of lakes connected by short stretches of rapid rivers. After they have attained considerable volume and as they approach the margin of the interior table-land they begin to assume a true river character; they flow with a moderate current, broken by short falls and heavy rapids, in old river valleys cut below the general level. Near the margin of the table-land the valleys become deeper, and the rivers are almost a constant succession of heavy rapids and falls until they reach the lower country, where they flow with a moderate current, with but few small rapids, in a distinct river valley between clay and sand banks of Post-Pliocene age. (23, p. 20.)

On the Stillwater River he notes that the country does not slope with the river, and consequently the bottom of the valley for several miles above Natuakami Lake is about seven hundred feet below the general level of the surrounding region. Referring to the Kaniapiskau, one of the streams flowing from central Labrador northward to Ungava Bay, he states:

> For sixty miles below the lake [Kaniapiskau] the river, like all the streams of the central area, flows nearly on a level with the general surface, or rather fills all the depressions along its course, and in consequence is made up of a succession of lake expansions connected by short stretches of rapids, where the river is often broken into several channels by large islands. Below this distance the channel contracts and in five miles the river descends more than two hundred feet into a distinct valley well below the level of the surrounding country; and from there to its mouth always follows a distinct ancient valley cut down into the solid rock from 300 to 1,000 feet below the surrounding country. Between the first and the second gorge, which is about eighty miles lower down stream, the river is almost a continuous succession of heavy shallow rapids so bad that the stream is not used by the Indians. At the second gorge or Eaton Cañon, the river passes through a narrow cleft in the

rocks and falls more than three hundred feet in less than a mile. Below Eaton Cañon the river continues with a very rapid current for one hundred and seventy-five miles to where it joins the Larch River, a very large branch from the westward. (24, p. 210.)

One of the best examples of this type of river valley is that of the Hamilton River. Low's description is as follows:

The Hamilton River like the Koksoak and all the other large rivers of Labrador flows in a distinct valley cut down far below the general level of the surrounding country. If Hamilton Inlet, which is only a portion of the ancient valley now sunk below sea level, is included, the main valley extends inland nearly four hundred miles, and its present bottom is from six hundred to twelve hundred feet below the surface of the surrounding table-land. The upper portion of the river flows nearly on a level with the lower portions of the central tableland, and like the Kanapiskau spreads out into lakes or in other places is broken into several channels by large islands, so that it is often difficult to define or follow the principal channel. Near the Grand Falls the river changes from a meandering stream that follows the lower levels of the general surface, and contracting into one channel is precipitated into the ancient deeply cut valley. In twelve miles this great river, with a volume nearly equal to that of the Ottawa where it flows past the Capital, falls seven hundred and sixty feet from where it issues from a narrow cañon into the wider valley. The first part of the descent is seven miles of rapids with a total fall of two hundred feet. The river then contracts into a narrow inclined, rocky trough down which it rushes with a tremendous velocity and is spurted out in a solid mass over a steep precipice into a circular basin three hundred feet below. The basin into which the river falls is about two hundred yards wide and is nearly surrounded with vertical rocky cliffs, that rise five hundred feet above the water . . . . From the basin the river rushes out through a narrow cañon cut vertically into the rock at right angles to the falls. This cañon on the level of the surrounding table-land is from one hundred to three hundred feet wide, but at its bottom is often less than fifty feet across. Down this narrow zigzag gorge the river rushes in a continuous rapid with a fall of two hundred and sixty feet from the basin to where it issues into the wider ancient valley eight miles away. (27, p. 212.)

In the report on the southern portion of Portneuf, Quebec, and Montmorency counties, Quebec, Low notes that

The rivers falling from the high interior plateau are much broken by rapids and falls, and owing to their rapid descent are liable to great and sudden variations in volume of discharge . . . . The valleys of the rivers and their tributary streams are deep, with almost perpendicular walls, rendering cross country travel very arduous, and in places impossible, while the dense forest growth adds to the difficulties and hides many of the rock exposures. (25, p. 7.)

The valley of the Betsiamites, described by Low (20, p. 7), and the well-known gorge of the Saguenay are two of the most striking of these deep valleys which traverse the St. Lawrence swell.

The drainage of the central portion of the peneplain south of James Bay presents somewhat similar features. Barlow draws attention to the fact that

> Probably one of the most interesting of the physical features presented by the district is the valley occupied by Lake Temiscaming and the Ottawa River. The greater portion of this valley is a very steep rocky gorge, fringed on either side by lofty hills or perpendicular cliffs which rise abruptly

FIG. 13.—Post-glacial gorge of the Hamilton River, immediately below the Grand Falls. The vertical cliff on the left has a height of 500'.
(*Photograph by A. P. Low, 1894.*)

> to a height of from four hundred to six hundred feet above the surface of the water, while the average of a large number of soundings indicate that the lake has a mean depth of over four hundred feet. The depression, therefore, occupied by these waters would be about one thousand feet below the level of the surrounding country, and as the bottom of the lake, wherever examined, consisted in the deeper portions of a very fine gray unctuous clay or silt, this depth may have been much greater before the accumulation of this material. From Mattawa to the mouth of the Montreal River these abrupt and rocky shore-lines prevail, but above the mouth of this stream the lake undergoes considerable expansion and the shores exhibit a more gradual slope towards the surface of the water. The traveler ascending the Ottawa River is thus usually impressed with the mountainous character of the district, but an ascent of the hills on either side at once shows that the adjoining country is comparatively level, and that what appeared as a range of hills are in reality the inclosing walls of this great valley. (4, p. 23.)

He also states that "the Mattawa and Montreal Rivers, in a lesser degree the Sturgeon and Temagami Rivers, occupy rather deep and important depressions in this rocky plateau."

On the western arm of the peneplain the upland still presents the same general features. The head-waters of all the rivers flowing to James Bay, where they flow over Archæan rocks, alternate between long lake-like expansions with little current, and short, contracted portions characterized by rapids and falls. Where they cross the ancient or modern coastal plains the fall is uniform, and usually, except at times of high water, they present an almost unbroken succession of small shallow rapids full of bowlders and gravel bars. (See Low, 23, p. 18.)

Tyrrell draws attention to the fact that

> A particularly noticeable feature of the "Barren Lands" is the absence of valleys for the rivers. The Telzoa River probably the largest stream in all that country, is, through the greater part of its course from Daly Lake to the head of Chesterfield Inlet, merely a succession of lakes of larger or smaller size lying in original depressions in the till or rock, connected by stretches of rapid water flowing in one or more shallow, tortuous and often ill-defined channels frequently chocked with boulders. (33, p. 395.)

The deep, steep-sided gorges cut below the level of the plain are less in evidence on its western part. Shallower gorges occur, but generally only for short stretches along the rivers. There are, however, a number of broadly open valleys, more or less occupied by sediments, which have been provisionally classed as Cambrian. Tyrrell states

> It would seem probable that the drainage has always followed the main valleys which still trench the surface, running more or less at right angles to the mountains. The pre-Cambrian valley of Chesterfield Inlet, extending eastward towards Hudson Strait, and westward towards Great Slave Lake, and the post-Cretaceous valley of the Saskatchewan, extending towards the lower valley of the lower Nelson River, and many other valleys running more or less parallel to these, go to prove the general correctness of this statement. (35, p. 149.)

The partial re-excavation of some of these depressions, occupied at least in part, by early Paleozoic sediments has given rise to the eastern extension of the basins of Lake Athabasca, Great Slave Lake, and Great Bear Lake. Reference has already been made to the valley of Chesterfield Inlet, and it is not improbable that Wager River (or Inlet) north of this owes its origin to a similar cause.

Valleys similar to these, containing sedimentary rocks, are also known to occur in the Labrador area. Low has reported the finding of sediments, provisionally classed as Cambrian, in the valleys of the Kaniapiskau and the Upper Hamilton Rivers. A somewhat similar series of sediments, the Manitounuck Series of Bell, occur along the east coast of Hudson Bay—lying below the level of the edge of the interior plateau, dipping seaward at low angles, presenting a well-defined cuesta front toward the plateau. In places the foot of the cuesta is submerged, but the unsubmerged portions form a series of coastal islands.

A series of sediments, for the most part classed as Cambrian, also occur in the Mistassinni basin. Ordovician outliers are found in the Lake St. John basin; Ordovician and Silurian strata occur in the northern part of the deep valley before noted as being occupied by Lake Temiscaming. Ordovician strata are also found in the Lake Nipissing basin. North of Lake Superior, particularly to the south and west of Lake Nipigon, is a well-developed series of non-fossiliferous ferruginous sandstones and dolomites resting upon the peneplain, and showing typical cuesta form. Subsequent to the development of the cuesta form on these sedimentary outliers they seem to have been overflowed with diabase sheets, and in some cases the earlier land form has been preserved beneath the more recent flow.

5. *Topographic depressions.*—A comparative study of the various depressions which go to make up the relief of the peneplain surface, as it is today, suggest a provisional recognition of three distinct types.

a) The broad, shallow depressions between the more or less hummocky or undulating ridges which occur upon the upland itself, and which are probably in the main of contemporaneous origin with the surface of the peneplain, and are presumably due to local differential erosion, and subsequent denudation.

b) Broad, open depressions, which are generally in part occupied by sediments provisionally classed as Cambrian.

c) Deep, narrow channels, in places gorges, with steep, often inaccessible sides, distinctly incised beneath the level of the adjacent upland. (These are of two types, short and relatively shallow, and long and generally deep.)

a) *The upland depressions.* — In considering the drainage features of the whole peneplain, it is found that the drainage basins of the larger river systems indicate approximately the existence of large, amphitheater-like basins, each draining toward its own median axis. When the topography is considered more in detail, it is found that each of these drainage basins is divided into a number of minor basins, each with its local drainage system more or less imperfectly developed. For the most part the minor depressions of these local basins are occupied by small lakes, usually with rock basins, the water in each of these local basins spilling over the lowest edge to the next lowest one below. The depth of these minor depressions on the peneplain surface below the level of the water in the basin rarely exceeds, and is usually much less than, the elevation of the adjacent ridges above the same datum level. In parts of the area the surface of the peneplain submerged approximates as much as 25 per cent. of the whole.

The water filling of a number of the adjacent minor depressions may reach an elevation sufficiently great to unite many of them into a large lake or series of lakes, dotted with islands, where the ridges between the adjacent minor basins project above the surface of the water. These island-dotted lakes are one of the most characteristic features of most of the uplands. One of the finest and an easily accessible example of this type of lake is Temagami in "New Ontario." The eastern shore of Georgian Bay, with its "thirty thousand islands" marks the place where a small section of the peneplain passes beneath the water level of Lake Huron.

Upland lakes, in basins of the type here described, when occurring in the vicinity of divides, often have outlets in two directions. At the present time Temagami has two outlets, a portion of its water eventually reaching the Ottawa River, and another portion flowing to Lake Nipissing and Georgian Bay. A rise of a few feet would give the lake four outlets. Reindeer Lake in eastern Athabasca is a large lake on a divide between the Churchill and Mackenzie River basins. A part of its waters flow south and then eastward *via* the Churchill River to Hudson

Bay, and part of the waters flow *via* the Cochrane River and Wollaston Lake to Lake Athabasca, and eventually reach the Arctic Ocean. Similar lakes, both large and small, with outlets in two directions, are quite frequently found manywhere upon the peneplain.

b) *Depressions containing sedimentary deposits.*—The occurrence of valleys occupied by sediments which have been assigned to the Cambrian has been reported by Low in Labrador and by Tyrrell in northern Keewatin and eastern Mackenzie. Reference has already been made to some of these in a previous section; the occurrence of Paleozoic sediments in the basins of Lakes Nipissing, Temiscaming, St. John, and Mistassinni has also been noted.

Low in describing these valleys in Labrador mentions that the streams are often from 500 to 1,000 feet below the level of the plateau. The heads of the valleys are from 100 to 300 miles from their mouths, and at the upper ends the rivers descend from the level of the interior in a succession of heavy falls through narrow gorges, where processes of erosion are at present slowly extending and deepening the valleys. The valley of the Hamilton River he describes as being from 700 to 1,200 feet below the level of the plateau. In some cases these ancient valleys have been more or less filled with glacial débris, and the modern streams for parts or all of their lengths have taken new courses.

Some of the depressions in which these sediments occur seem to be ancient, broadly open valleys, and are considered by those who have had the opportunity of studying the region in the field as of pre-Cambrian age.—In the case of Chesterfield Inlet, Tyrrell notes that the sides are deep and in places cliffed. Back's description of the country immediately north of the east end of Great Slave Lake would lead one to infer that the sides of this valley were also well defined.[1]

In the Labrador regions the margins of the depressions in which the pre-Cambrian sediments (so-called) occur are well defined. This is strikingly true of the lower and partly sub-

[1] See also Fig. 9.

merged valley of the Hamilton River. The Mistassinni depression is bounded by a well-marked scarp on the southeast, and a less definite, but still distinct, margin on the northwest.

The Lake St. John basin seems to be of a distinctly graben type; its margin is well defined, often cliffed or scarped; and all the streams tributary to the lake spill over the edge of the basin from the adjacent upland each in a series of waterfalls and cascades, often visible many miles away from the open lake.

The sediments in Lake Temiscaming and Lake Nipissing basins are in valleys lying below the level of the plain. The sediments in the vicinity of Lake Nipigon rest directly upon the plain, and rise above its surface.

In the greater number of cases it seems that there is a well-defined margin to the valley. In the case of some of those in the localities referred to above it may be possible that they antedate the peneplanation epoch, and that the sediments lying within them have been partly re-excavated since then. In the case of Lake Nipissing and Lake Temiscaming depressions, and possibly in the case of Lake St. John and Lake Mistassinni, the depressions may also be of a date antecedent to the peneplanation.

Barlow notes with regard to the Lake Temiscaming depression, and of others in that vicinity, that they bear no significant relation to the direction of the movement of the glacial ice, in fact, they lie at various angles up to as much as ninety degrees to the general direction of the movement of the ice-sheet. He also notes that many of them cut across hard and soft rocks alike, and are independent of the strike of the structure of the rocks.

The character of the bounding walls, and the preservation of Paleozoic sediments in the bottoms of many of these valleys, would suggest that they are graben formed after the deposition of the sediments, and that the sediments are preserved in them because they were below the base level of erosion at the time when the balance of the similar sediments on what are now the adjacent uplands were removed. The fact that in many cases streams cascade down the sides of these valleys in ungraded channels suggests that this faulting has been quite recent. It is doubtless possible that in some cases where these valleys open

out on the coast, that hanging lateral valleys may be due to the deepening and widening of the main valley by an ice-stream; but many of the type of depressions here referred to not only lie in regions which can never have been at the edge of the ice-sheets when they were in motion (or at least at their points of discharge), but seem to be completely inclosed by the bounding scarps except for the narrow outlet through which the present drainage passes.

In the majority of cases there is not sufficient available evidence to warrant an extended discussion of this very interesting problem.

c) *Gorge and canyon valleys.*— Narrow, steep-sided valleys and gorges, sometimes many miles in length, sometimes only extending for short distances, are of frequent occurrence in various parts of the peneplain. Reference has already been made to a number of them which are known to occur in the Labrador area, through which the drainage of the interior upland passes down to Hudson Bay, to the River St. Lawrence or to the Atlantic Ocean. One of the most interesting of these is the gorge of the Hamilton River, described by Low[1] as occurring above the more broadly open, partly submerged pre-Cambrian valley (so-called) of the lower part of the same river. The numerous rivers which enter the Gulf and River St. Lawrence from the northwest in every case pass through deep, steep-sided valleys, often canyons with unscalable walls, at times cut to a depth of over one thousand feet below the level of the peneplain. The valley of Moisie has been described by Hinde, the Bersimis by Low, the Saguenay the best-known of all, by Laflamme and Dumais.

Farther west the depression occupied by the lower part of Lake Temiscaming and the Ottawa River as far down as Mattawa seems to belong to this category. In the immediate vicinity of Lake Temiscaming there are a number of other gorges and valleys, the former much narrower and smaller than the Temiscaming depression, cut beneath the surface of the plain, at times even across weak and hard rocks alike, independent of the structure.

[1] See above p. 641.

The edge of the plain along the north shores of Lake Huron and Lake Superior stands at a considerable elevation above these water bodies, and there are many south-flowing streams in this locality occupying steep-sided valleys incised well beneath the peneplain. In the northwest part of the area similar gorge-like valleys occur, but they are generally smaller, shorter, and are less prominent features.

So far as known, the valleys of this class are never found to be occupied by pre-Cambrian sediments and always have a well-defined "shoulder,"[1] where the gradient curve of the valley side intersects the flatter curve of the upland surface, and in their general relations suggest that they date their origin from a time subsequent to the period of planation.

6. *Monadnocks.*—In the various descriptions which have been quoted above it will be noted that frequent reference is made to the occurrence of residual domes and ridges which stand prominently above the generally even surface of the peneplain. In northwestern Labrador there is a narrow range of mountains described in part by Bell (5) and by Daly (9), reaching in places an elevation of about six thousand feet above sea-level. The range is narrow, having only a width of about fifty miles. The somewhat meager descriptions would lead one to infer that this range, like that of the less rugged Adirondacks in New York state, represents residual mountain peaks which have not been reduced to the peneplain condition. With the exception of these two small and widely separated areas, the residual elevations rising above the peneplained surface are generally more or less isolated domes and ridges, and they are found in all parts of the region. Their elevation and development seem to depend largely on the character of the material of which they are composed, and of the material by which they are surrounded. The most prominent monadnocks known within the area seem to be those mentioned by Barlow and McOuat as occurring in the region west and north of Lake Temiscaming, where hard quartzite ridges stand in places as much as seven hundred feet above the plain. The Baraboo ridge in Wisconsin,

[1] See 41, p. 155.

an outlying monadnock ridge rising through the Paleozoic sediments, is comparable with these, and it is not impossible that its height above the peneplain on which it stands, but whose surface in this vicinity is obscured by the sediments, may be even greater.

Another excellent example, and one of considerable historic interest in connection with Logan's early work on the geology of the Archæan, is Trembling Mountain, lying north of the Ottawa River, and to the northwest of the city of Montreal, The mountain is a domed monadnock rising over 800 feet above the general level of the plateau, and about 2,380 feet above sea-level.

7. *Lakes.*—Reference has already been made to the fact, characteristic of the whole area, that the majority of the minor depressions on the surface of the peneplain form innumerable rock-basins in which the water gathers to form large and small island-dotted lakes. In addition to lakes of this class, which are usually very shallow and with very intricate shore lines, we occasionally find several other types.

One of the commonest of these is longitudinal lakes occupying old valleys which are more or less blocked by débris or by other geologic causes, in some cases presumably differential uplift. There are other examples of long, narrow lakes whose depressions are ascribed to the erosion of softer dikes. Over fifty years ago Agassiz drew attention to the fact that many of the bays and points on the shores of Lake Superior owed their origin to the erosion of soft dike rocks. More recently Bell has explained the origin of certain channels along the Lake Huron shore, and the longitudinal basins of certain inland lakes north of Lakes Huron and Superior, by a similar process.

The most interesting of the lakes of the longitudinal type is that of Temiscaming and the "Deep River" of the Ottawa adjacent to it. Dr. Barlow's description of this lake has already been mentioned, and his description of the character of the depression which it occupies has been quoted above. Whether the depression is of the graben type, somewhat similar to Lake Tanganyika in central Africa, or whether it is to be ascribed to the blocking or warping of a preglacial gorge is at present

impossible to say. The character of the walls and the occurence of silurian sediments within the basin certainly suggest that it is of the graben type.

THE PENEPLAIN FACETS.

The relations of the Paleozoic sediments around the southern border of the plain to the peneplain surface suggest several interesting problems. In a former paper (41) the writer drew attention to the fact that there seem to be some grounds for surmising the existence of at least two peneplains cut upon the Archæan rocks and meeting at a very low angle. The data on which this suggestion was based are in part repeated here, with the addition of a few facts since obtained which bear on the same subject.

In the earlier part of this paper attention was drawn to the remarkably even sky-line exhibited by the plain everywhere in the interior, and it was mentioned that the average gradient in the interior rarely exceeded four feet per mile. In the central part of the province of Ontario it is found that radially from the upland surface in the vicinity of Haliburton Lake (the highest point in this part of central Ontario) to a number of points along the base of the Ordovician escarpment between Georgian Bay and Kingston, the average gradient over the surface of the peneplain is nearly nine feet per mile. At Toronto a well boring has shown that the crystallines are about eleven hundred feet beneath the present surface. Two other borings—one at Cobourg and the other in the township of South Fredericksburg—indicate that the floor is over five hundred and over six hundred feet respectively below the surface at these localities. The average gradient beneath the sedimentary cover along a series of lines from the foot of the Ordovician escarpment to the bottoms of these borings indicates that the gradient beneath the cover varies from twenty-two feet per mile in the western portion of the district to over forty-one feet per mile at the eastern end. The relative attitudes of these two surfaces are represented in Fig. 14, where *AB* represents the edge of a cross-section of the plain beneath, and *BC* the edge of a cross-section of that outside the sedimentary area. Such a comparison is quite justifiable

because the numerous outliers north of the edge of the escarpment indicate that the surface over which the average gradients on the Archæan have been taken has been at one time buried beneath the sediments, and this surface has a remarkably even sky-line.

In the province of Manitoba, at Deloraine, a well has been driven to a depth of 1,943 feet below the surface and 108 feet into the Dakota sandstone. The bottom of the well lies about 299 feet below sea-level and 1,009 feet below the surface of Lake Winnipeg. The Archæan surface beneath the sediments, making no allowance whatever for Silurian and Ordovician sediments which probably underlie this sandstone, must thus

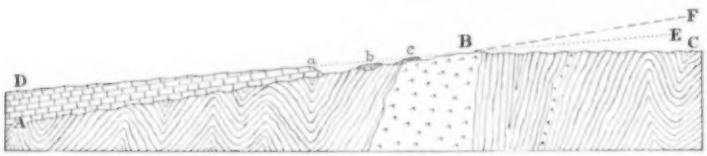


FIG. 14.

have a gradient of about six feet per mile, and probably it is actually more than double this amount. East of Lake Winnipeg the gradient upon the Archæan to the summit of the subdivide, along the same line, is less than two feet per mile.

The relative positions of these two plains (reference to a possible third plain upon the surface of the Paleozoic sediments is here omitted) suggest certain problems, which may be summarized thus:

1. Do these two plains represent two distinct periods of planation?

2. Are *AB* and *BC* of the same age, but now discordant by warping?

3. Did the former plain *AB* once extend upward in the direction of *BF*?

4. Is the discordance between *AB* and *BC* produced by warping?

It should be added that the data at present in hand are not

enough to determine whether *AB* and *BC* represent two intersecting plains, or are portions of a continuous curve. It may also be noted that the data given above, taken in conjunction with the progressive overlap of higher and higher geologic horizons upon the peneplained surface, as one proceeds toward the northwest, suggest that there are even more than two peneplains. Each plain may be regarded as a facet cut upon the Canadian shield. During the long interval of Paleozoic time a succession of these facets intersecting at very low angles would be formed as the land slowly sank and the successive formations were laid down. The great central part of the area upon whose surface the remarkably low gradients have been observed would represent the youngest of the facets, the region upon which the planation processes had acted longest. The partial removal of the Paleozoic covering has already exposed several of the older facets.

Similar relations to those noted above as occurring in Ontario between two plains of degradation upon the crystalline rocks have been found by Van Hise in Wisconsin (38), and by Smyth in the region south of Lake Superior (31). Darton has described a somewhat similar case in Virginia (10). In the Grand Canyon of the Colorado we have an actual transverse section of two such intersecting plains, both older than the Cambrian, but meeting at a much higher angle than that noted for the two plains near the margin of the Canadian shield.

SUMMARY.

From a physiographic standpoint the Canadian shield can be described as an ancient peneplain which has undergone differential elevation; has been denuded, and subsequently slightly incised around the uplifted margin. At several places on the margin, as exposed today, the dissection may be regarded as submature. Around the southern margin between Montreal and Winnipeg there are traces of a peneplain (or probably more than one) of still earlier date, upon which Paleozoic sediments were laid down, and which has been uncovered by processes of degradation and denudation since the differential uplift of the latest

peneplain. The region is now in an extremely youthful stage of a new geographic cycle. It is bordered on the west and south by a belted ancient coastal plain whose mature drainage adjustments have been subsequently modified by glacial action, and in part by differential uplift. On the southeast the normal development of the ancient coastal plain has been in part retarded and modified by orogenic movement and dynamic process. Traces of the normal coastal plain development are, however, in evidence in a number of localities between Montreal and Anticosti.

The inner concave margin of the plain is marked by a depression occupied by the waters of Hudson Bay. To the south and southwest of the southern part of the bay there are traces of an ancient belted coastal plain with a convex south-facing cuesta development. For the most part this ancient coastal plain is buried beneath glacial débris and the sediments of the young coastal plain, the latter being superposed upon the former. This young coastal plain borders Hudson Bay on all sides, and the consequent drainage from the interior has incised well-defined valleys in the soft glacial and marine deposits, the interstream areas being little dissected. This modern coastal plain is of varying width up to a maximum of nearly one hundred and fifty miles.

The denuded peneplain surface, although destitute of mantle rock *in situ*, is strewn with glacial débris often of considerable amount. In the interior of Labrador this material is often very coarse, consisting of huge blocks and bowlders, with, however, considerable amounts of finer débris. In the parts to the south of James Bay, particularly in the Moose River basin and as far south as the height of land, the plain is almost completely buried beneath unmodified and modified glacial drift. Glacial drift in less amount, often fine-textured, at times coarse rock débris, occurs over the whole of the western portion of the peneplain. There are, however, areas of considerable extent where the amount of drift is very limited.

In the Labrador region there is a limited forest growth in the hollows. Most of the interior is bare and barren. In Quebec and in Ontario south of James Bay the region is densely forested.

The forests extend over the western portion of the plain to a short distance north of Great Slave Lake. Beyond this the region is treeless, moss-covered tundra. South of the forest line there are frequently large areas floored with glacial drift and forming numerous muskegs (or swamps) above whose surfaces the crystalline ridges and glacial kames and eskers project.

SOME PROBLEMS OF GENERAL INTEREST.

Aside from the strictly geologic problem of the origin and relations of the rock complex of which the Canadian shield is composed, there are a number of secondary problems of interest alike to the geologist and to the physiographer. Although it is not proposed to enter into an elaborate discussion of any of these problems at present, the time seems not inopportune to outline a few of those which are of general interest, and which are closely associated with one another.

1. *The former extent of the Paleozoic cover.*—The first of these which suggests itself is one to which reference has often been made. Did the Paleozoic sediments ever extend across the interior divide? Opinion seems somewhat divided on the answer to be given to this question. No doubt additional light will be thrown upon it when the fauna of the Paleozoic sediments occurring to the south of Hudson Bay can be adequately studied. The occurrence of the inlying areas of Paleozoic deposits, already referred to as occurring in the several depressions between Lake Mistassinni and Lake Nipigon, is generally regarded as strong evidence of the extension of these sediments at least across that portion of the plain which lies to the south of Hudson Bay.

To the physiographer the problem has an added interest from the fact that, if these sediments once extended completely across the peneplain, the questions arise: Is the present surface of that plain approximately the one upon which they rested; or has the surface upon which they were deposited been removed long since? Would it be represented by the extension of the peneplain of earlier date (which, it has seen shown above, probably exists) toward the locus of the present main divide?

The answer to these queries seems to be intimately associated

with the second problem which suggests itself: What is the origin of the peneplain surface as to the time and process? At present it is quite certain that the evidence available is inadequate to solve the problem.

2. *The subaërial origin of the peneplain and the date of origin of the principal plain.*— As already noted, the stratigraphic studies of Walcott, Schuchert, Ulrich, and others have shown that at the beginning of Ordovician time the greater portion of the Canadian shield was above sea-level, and that since early Cambrian time it has never been wholly submerged. The work of Laflamme, Adams, Lawson, and others has shown that along the southern margin of the peneplain from Lake St. John to Lake Winnipeg, where the plain passes beneath the Ordovician sediments, it possesses the same hummocky character and fresh rock surface as it does in districts remote from the margin. Between the farthest outliers (exclusive of the outlying areas which may owe their preservation to the downthrow of fault blocks) there is a belt of the uncovered presedimentary surface, which shows all the features everywhere characteristic of the modified peneplain. Hence not only must the portion of the plain adjacent to the areas now overlaid by Paleozoic sediments be of pre-Ordovician date, but the dissection which it has undergone must also be pre-Ordovician. The dissection is regarded as of different date from the planation, because the gradient curves of the valley sides are not accordant with the flatter curves of the surface of the plain, often meeting the latter at an angle. The valleys are regarded as younger than the plain, because in no single instance do they contain sediments that have been derived from the adjacent plain. Along the margin of the plain their filling is always of the same materials as that with which the plain itself is covered— usually Ordovician limestone. The forms of the valleys and their relations to the plain are such that they would not be attributed to marine erosion.

During the transgression of the Ordovician sea it is conceivable that the earlier surface of subaërial origin may have been replaced by one of marine planation, assuming a time interval long enough. It is now generally admitted that during a time

interval of sufficient duration to permit of the foundation of a plain of marine planation of any considerable breadth, the land of a very much larger area would be reduced almost to base-level by subaërial processes. If so, temporarily assuming that the margin of the peneplain, from which the Paleozoic sediments are known to have been removed, owes its plain character to marine planation, it would follow that the interior portions were principally of subaërial origin. If the marginal portion of the plain owed its plain character to marine erosion, we should expect to find the débris removed from the ridges deposited in the hollows, since the waves and currents tend always to produce an evenly graded floor. In the field no trace of this can be found. The Ordovician limestones often rest directly upon the plain surface and pass down into the adjacent hollows where the sides are not very steep. Where they are steep the lower beds abut against the valley walls and are conformably overlaid by beds which rest upon the plain. Nowhere has any accumulation which can be regarded as distinctively a product of marine planation been reported. Fossils (corals, crinoids, orthoceratites) are found in the lower limestone beds sometimes within a few inches of the Archæan rock, in some few cases actually attached to it. From the fact that these are not comminuted it may be inferred that the conditions of transgression, at least in the localities where they occur were such that the waters were moderately quiet; and from the absence of arenaceous deposits in many of the localities it may be concluded that the rate of transgression was comparatively rapid — presumably too rapid too permit of significant marine planation.

That the rate of depression was probably too rapid for significant marine planation is also suggested by the fact that everywhere beneath the surface of the sediments the Archæan rocks are found in a perfectly fresh and undecayed condition.

Thus although the area must have been exposed to marine planation at the time of Ordovician submergence there is reason to believe that the conditions of submergence were such that the pre-existing surface which must have been of subaërial origin can have been but little modified. The distribution of overlying

areas of Paleozoic sediments suggests that the relatively rapid depression which continued through Ordovician time continued until near the close of the Silurian, and it is probable that the middle part of the plain was completely submerged. The eastern and western parts of the plain were still above water-level. If the middle portion was completely submerged at this time, it must have been re-elevated and the sedimentary cover in part removed, for Devonian corals have been found in the Hudson Bay basin with their bases attached to bosses of Archæan rocks. The Devonian sandstones flanking the peneplain on either side also suggest that the middle portions of the plain were subject to subaërial degradation during at least a portion of Devonian time. Of the history of the greater portion of the region from the close of the Devonian to the beginning of the Pleistocene there is no sedimentary record closely associated with the peneplain.

The late Mesozoic has been shown to have been a period of extensive peneplanation throughout most of North America. In New York and Pennsylvania to the south, in Wisconsin and Michigan to the southwest, the remnants of the planation surface have been recognized. In the far northwest strata classed as Cretaceous are found resting apparently upon the peneplain surface. The relations of Cretaceous sediments to a surface apparently coincident with the plain cut upon the Archæan rocks of Wisconsin also suggests that this plain is Cretaceous. It thus seems not improbable that the planation processes of the same period, working northward and eastward from these areas and southward from the Arctic regions, may have in part produced the younger of the two (or more) plains upon the Archæan areas in Canada.

The southern margin of the plain south of Methy portage and around nearly to the city of Montreal is probably of Paleozoic (and pre-Paleozoic) age, since there is little doubt but that it was once covered with Paleozoic sediments. Whether this is true of all that section which lies between the outliers before noted as occurring in the basins of a number of lakes near the central divide seems doubtful. The more detailed study of these basins

may show that the Paleozoic sediments which they contain, and which are in every case, except that of Lake Nipigon, significantly below the level of the peneplain, are preserved because thrown into their present protected positions by the downthrow of graben blocks. If so, the probability of this plain being of Cretaceous age will be strengthened. What seems to be a comparable case is known in Scandinavia. The earlier sedimentary rocks were dislocated by a series of faults; later planation left only a few small patches at base-level upon the downthrown parts of the tilted blocks. Subsequent elevation of the whole area, and erosion of these softer remnants, produced a series of depressions in some of which are still found isolated patches of the soft rocks. The lower portions of these depressions frequently form lake basins, the most important of which are Boren, Roxen, Glau, and Braviken.[1]

So far as the geological record is known, it appears that the Labrador portion of the peneplain has never been submerged since Paleozoic time. To this long exposure to subaërial erosion may be attributed the extremely low average gradients of approximately one foot per mile, the lowest found anywhere upon the plain.

3. *The origin of the basins, valleys and gorges.*—The minor basins upon the upland surface, now forming the basins of small lakes, undoubtedly owe their origin to processes of differential disintegration and subsequent erosion and denudation by some agency. The last denuding agent in operation was, of course, the Pleistocene ice-sheets. There is some question, however, as to whether the denudation of the surface is due to these ice-sheets, or to some earlier ice-sheet, or to some other cause. Reference will be made to this in discussing the fourth problem.

The origin of the valleys and gorges incised beneath the plain to a significant degree presents some features of particular interest. Those in which the Cambrian sediments lie may be older than the sediments which they contain, and in that case would be of much earlier date than the main peneplain surface.

[1] See also Eighteenth Annual Report State Geologist of New York, Part V, pp. 143 ff.

The gorge-like valleys, free from Paleozoic sediments, and the canyons, one would be inclined to think, date their origin from a time subsequent to the planation period. Their immature form, as compared with the broader pre-Cambrian valleys (so-called), and the absence of any Paleozoic sediments between their walls suggest this. Most of them are pre-glacial, but some few are post-glacial.

The processes by which they were excavated no doubt were various. Mention has already been made of the opinions of Agassiz and Bell that some of them owe their origin to the erosion of soft disintegrated dike rocks. This may be true in a few isolated cases. In the great majority of cases, however, particularly of the larger of these gorges, other and more general processes must have been in operation.

Given time enough, there can be no question but that the normal processes of river erosion could produce these deep canyons or steep-sided valleys. So far as we know at present, this seems to have been the process by which most of the deep gorges and canyons cut below the level of the Labrador peneplain were excavated. Low notes with respect to the canyon of the Hamilton, just below the Grand Falls, that the river in its erosion of this gorge has been guided by two series of joint fractures, so that the canyon has a somewhat zigzag course. Mr. Low has also drawn the writer's attention to the fact that there are several instance where an old valley has been blocked by glacial débris, and the streams flowing in the upper portions of the valleys are turned aside, and have already cut well-defined canyons, in some cases of considerable length, in the crystalline rocks. It is to be noted that the canyon of the Hamilton River enters the older valley, to which reference has already been made, from the north side. The old valley continues inland for a considerable distance beyond the junction of the present Hamilton River, *via* the canyon, with the lower part of the stream in the older valley. Mr. Low regards this canyon as of post-glacial origin and due to erosion by the large stream which now rushes through it.

The problem of the origin of the deep canyons across the

Laurentian swell by which the drainage from the main divide in the interior of Labrador reaches the St. Lawrence River is much more complex. One would expect the drainage of such a region to find its way outward toward the southwest, somewhere along the line of the present St. Maurice River. At the present time almost all the streams flow nearly at right angles to this apparently normal direction and cross the St. Lawrence swell in very straight courses by deep, steep-sided gorges or canyons.

The transverse drainage has been explained by assuming that the gorges through which the streams flow were produced by some cataclysm, either by the production of gigantic gaping fractures or by the down faulting of narrow graben blocks. The only evidence upon which this theory is based seems to be the existence of the gorges themselves, and the apparent difficulty of otherwise accounting for the courses of the incisions in a direction which is almost at right angles to what would be considered the normal one. There are, however, at least two other well-known processes by which features such as these could be normally developed.

In the first place, the swell may not have been in existence at the time when the streams were first beginning to flow and the gorges were not cut. The edge of the plateau may have been arched up slowly by the same forces which produced the Appalachian folds of the New Foundland and Acadian areas,[1] or by more recent dynamic processes. Provided this gentle arching proceeded slowly enough, the streams might have persisted in their original direction, apparently a consequent one (as suggested below) sawing their way into the ridge as rapidly as it rose. In brief, the streams may be *antecedent* rivers. While this process was going on in the southeast, the rivers on the other side of the main divide would, provided they had an equal capacity for work—a function of their volume and grade—have been competent either to have cut out longer and deeper gorges or to have widened their valleys. The information at present available is not sufficient to decide the question. Mr. Low has drawn

[1] Daly has recently shown that the post-Pleistocene beaches on the northeast coast of Labrador have undergone differential elevation since they were formed (9).

the writer's attention to the fact that the bottoms of the channels of the westerly and northwesterly flowing streams are almost graded, although, on account of the steepness and shortness of the descent from the plateau to the coastal plain, they are an almost continuous series of impassable rapids. On the other hand, in the case of the channels of many of the streams flowing to the St. Lawrence we find a series of step-falls or rapids with quiet reaches above and with steep canyon walls beside the falls, so that these latter, though they have cut out deep valleys, are yet in a less mature stage than those on the other side of the divide.

It should also be noted that the general direction along which the streams would develop by normal erosive processes would be determined, as in the case of the gorge of the Hamilton River, by lines of structural weakness in the rocks, not necessarily by lines of open fracture.

A second theory would regard the majority of these valleys as the incisions of *superposed streams*. The Paleozoic sediments in the basin of Lake St. John are usually supposed to indicate a transgression of the Paleozoic sea into this locality, and at least suggest that at one time the whole adjacent region was buried beneath the Paleozoic sediments. The small remnant of an ancient belted coastal plain found between Montreal and Quebec, and farther east in Anticosti and the Mingan Islands, show that there, where the Paleozoic sediments were undisturbed by the orogenic movements of late Paleozoic time, normal processes of erosion produced normal topographic forms. It seems not unnatural to suppose that consequent streams developed on the coastal plain would, when they reached the hard rock beneath, have still persisted in their initial consequent direction. In this connection attention may be drawn to a gorge on the Betsiamites River. Low writes:

> Next turning to the northeast, the river, for a distance of eight miles, breaks in a straight line through the Labradorite hills, which form almost vertical walls on either side, rising from two hundred to four hundred feet above the water (20, p. 7).

The description of the river course and the country on either

side, below and above this gorge, would suggest that the Labradorite hills here referred to rise as a monadnock above the level of the plain, and that the stream to cut through them must have been superposed upon them.

Whether these gorges were developed by catastrophic processes, or owe their origin to antecedent or superposed streams, or to some other cause, a few of them have probably been modified by subsequent ice-action. In all cases they lie in a position transverse to the direction of ice-motion. In many cases, particularly toward the northeast, the probability is that the ice, retarded in its progress from central Labrador by the ascent of the main divide, had little effect. Toward the center and western part of this division of the plain, in the vicinity of Lake St. John and elsewhere, the effect of the glacial ice in modifying these valleys is more apparent. Writing of his ascent of the Betsiamites River, Low mentions incidentally a tributary of this river which "descends into the valley by a beautiful falls, over one hundred feet high" (20, p. 6). The main valley varies in width from a quarter of a mile to over a mile, and is more or less filled with glacial débris. The relation of this tributary lateral valley to the main valley certainly suggests that the main valley has been significantly widened and deepened by a glacial distributary from the interior. The best-known of the gorges is that of the Saguenay. It is a typical fiord valley with ice-scoured sides. Its relation to the St. John basin suggests that it owes its present form to the scouring by an ice-stream which made its way outward from the basin. The Labrador ice, although retarded in its flow by the ascent of the main divide, would attain a considerable thickness in this basin after it had passed the divide. Although it probably, at one time, passed over the St. Lawrence swell, the main ice-stream, after leaving the St. John basin, moved toward the southwest. If, however, there existed a deep river canyon leading outward from the basin, similar to the many found farther northeast, the depth of ice in the basin and the tendency for the pressure to force the ice outward in every direction along the lines of least resistance would cause an ice-stream to pass out in this direction toward the St.

Lawrence, even at a time when no significant amount was passing over the subdivide between the basin and the river. This ice-stream, moving in a well-defined channel, would deepen and widen the pre-existing river gorge. It thus seems probable that the Saguenay gorge may be regarded as the channel of a glacial distributary from the St. John basin, and that it was in existence prior to the advent of the ice, as a stream channel similar in form to those which exist farther northeast and show no significant modification of form due to ice-action.

With reference to the older valleys, north of the main divide in Labrador, containing pre-Cambrian sediments, the descriptions available are inadequate to enable one to determine whether they have been significantly widened and deepened by ice-erosion. In the case of the old valley of the Hamilton River lateral tributaries plunge or cascade over the margin into the main valley. This may be true of other similar valleys. It has already been intimated that the lack of adjustment between the tributary and the main valley may be due to relatively recent downfaulting of graben blocks.

Reference has already been made to the possible origin of the submerged gorge of Lake Temiscaming and the Ottawa River valley above Mattawa.

There are also a number of minor gorges, such as those mentioned by Barlow as occurring on the peneplain west of Lake Temiscaming, whose courses are in some cases transverse to hard and soft strata alike; or others, such as the gorge on the Upper Abitibi mentioned by Parks, which may be the channels of superposed streams, may have been eroded along the line of weak dike-rocks, or may be due to some other cause.

4. *The origin of the smooth fresh surface of the Archæan rocks.*—As has been intimated in the previous description of the peneplain, the old soil cover of subaërial origin has everywhere been removed. For this has been substituted a covering of material, much of which undoubtedly was derived from the Archæan terranes, but almost all of which has been brought to its present resting-place by the aid, direct or indirect, of the Pleistocene ice-sheets. Uncovered Archæan bosses often project above this

secondary cover. Everywhere that the bed-rock surface is known, whether covered or not, it presents a smooth, hard surface, free from the products of decay *in situ*. But not only is this true of the portion of the plain remote from the bordering Paleozoic sediments, but the work of Laflamme, Adams, Lawson, and others has shown that it is true of the localities adjacent to and *under* the Paleozoic cover.[1] Around the southern border of the peneplain, in the Lake St. John region, in the Moose River basin, and in a few other localities, the *actual contacts* between the Paleozoic sediments and the pre-sedimentary peneplain surface are known. In these cases it will be recalled that the peneplain facet upon which the sediments rest is probably that of an earlier cycle than the main Canadian peneplain. Now, in every case where these contacts have been met with and examined it is found:

1. That the crystalline rock surface under the sediments *in situ* is as little altered as in the ice-scoured surface perhaps twenty feet away.

2. In some few localities the pre-sedimentary crystalline surface retains some traces of decay, such as pits and pockets, now filled with small outliers of sediments, isolated more or less from the larger masses. Such pitted surfaces occur near Kingston. The best known case is that described by Bell as occurring on Benjamin Island, Lake Huron.

3. In only one locality south of the main divide has an actual arkose, which is presumably derived from the decay of near-by granitic rocks, been reported *in situ*. This forms the lowest member of the Ordovician series of the locality, and rests upon the fresh surface of a gneiss. The basal members of the pre-Cambrian rocks in northern Labrador are arkoses whose materials probably have not been transported very far.

As regards the apparently significant absence of arkose deposits (which might be regarded as old soils *in situ*) from beneath the Paleozoic sediments, it is to be noted that in almost all cases where the *actual* contacts between the sediments and the crystallines are known they occur at the summits or on the flanks of the crystalline ridges or domes. So far as the author

[1] For references and details see 41, pp. 146–53.

is aware, no case has been reported in which the *actual* contact between the two was located in or near the bottom of one of the characteristic pre-sedimentary basins. In fact, it unfortunately happens that most of these contacts must be below the present local water level. Hence at present we are only justified in stating that the summits and sides of the crystalline ridges beneath the sediments are as bare and as little decayed as are the similar ridges away from the sediments.

The condition of the surface beneath the sediments shows that processes which could produce a denuded fresh rock surface were in operation long before the Pleistocene. As to what these processes may have been there is considerable room for divided opinion.

Glacial erosion would seem to be competent to remove soft material from localities where disintegration had penetrated deeper than elsewhere. In the process it would scour the less disintegrated residuals and would thus produce the characteristic topography of the upland everywhere. The depth to which it would scour the bed rock itself is, of course, at present indeterminate away from the regions underlain by sediments, but it has produced no noticeable discordance between the parts of the buried crystalline ridges protected by the sediments and *closely* adjacent parts not thus protected. Again, if the bare, fresh surface has been produced by glacial scouring, it would seem that we must infer a pre-Paleozoic glacial period during which the sub-Paleozoic peneplain was scoured off. Of such a period, beyond the existence of the scoured plain itself, there is, in the regions under discussion, no known recorded evidence.

In this connection it may be well to recall that Dr. Geikie has described a somewhat similar surface occurring over a small area of Laurentian gneiss in northwest Scotland (Ross and Sutherland counties). He drew attention to the fact that this mammillated surface passed beneath the younger sediments, and notes that it is strongly suggestive of presedimentary glacial erosion.

The deep soils of the earlier peneplain might have been removed from the ridges, leaving them comparatively fresh, by

some such process of erosion as McGee describes under the title of "Sheet flood erosion" (28). He describes the surface of a portion of the subarid Sonora district in southern California as being a plain cut on crystalline rocks, with little soil cover *in situ*. In some features this plain resembles that of the Canadian peneplain, but it has relatively a very limited area. On the Canadian peneplain, however, the basins as well as the ridges are free from rock débris *in situ*.

The normal processes of subaërial erosion or of marine erosion do not seem competent to remove the material from the basins as well as from the ridges; and, in addition, they do not produce residual land forms with surfaces so little decomposed as are the crystalline surfaces everywhere.

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RIVER TERRACES AND REVERSED DRAINAGE.

THE south-central portion of New York state, or the plateau region, is furrowed by narrow north-south valleys. A study of a map made by combining the United States Geological Survey topographic sheets, representing the quadrangles lying between the Mohawk and the Susquehanna (Chenango-Chemung) valleys, draws attention to its peculiar drainage features and physiographic development. The presumption of reversed drainage, suggested in many instances by the map, is often borne out by a study of actual conditions in the field.

It is not the purpose of the present paper to consider the major features of a region extremely interesting and complex in its physiographic history, nor to correlate the analogous surface characters to be found in the numerous interrelated valleys. A future paper may consider these greater problems, and the presentation of many data gathered in field work extending over a large portion of the whole area.

These valleys of the dissected plateau region grow more trenchant in character and more rugged in their topography in passing from north to south. They all share in one common feature: that the preglacial floors are deeply covered with drift. The actual depth of filling may vary and fluctuate, but is from several hundred to something less than one hundred feet deep. Well borings of less than one hundred feet do not usually reach bed rock (Fig. 1). The locality herein considered is situated in Tioga county, N. Y., along the course of the Catatonk River. This stream heads in a flat, swampy divide on the valley drift, one mile east of the town of Van Etten, and, after flowing about nine miles in an easterly direction to North Candor, turns abruptly to the south. It maintains a practically southern direction for twelve miles, and, after uniting with Owego Creek, empties into the Susquehanna (Chenango) near the city of Owego.

The main stream follows a wandering course through the gravel-filled valley, never exposing rock *in situ*, except in one

place, where by swinging it has undercut the valley wall. The surface of the valley presents the aspect of a flat, level plain of drift-filling from valley wall to valley wall, in which the Catatonk River has excavated a shallow trench (Fig. 2). For the most part this stratified drift in the valley bottom is composed of rounded pebbles and coarse gravel, with intercalated beds of sand and at some depth beds of clay.

In the fall and spring the Catatonk River is rapidly converted

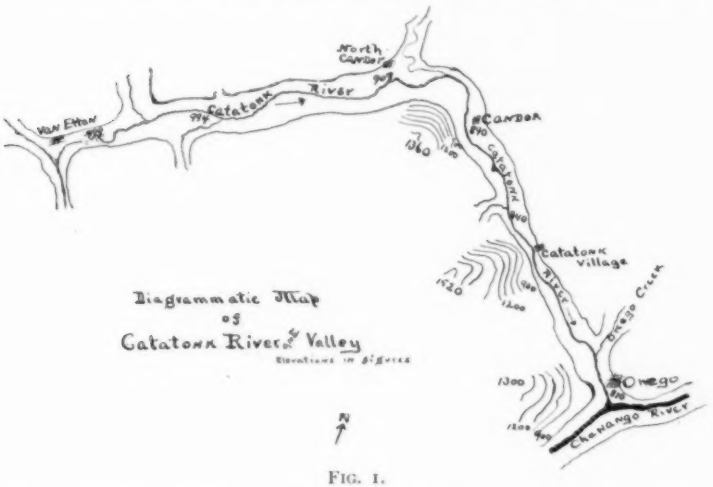

FIG. 1.

into a flooded condition by the rains and melting snows decending rapidly from the high valley walls in a diversity of small streams. Some of these latter are more or less persistent streams, having a drainage heading back onto the plateau, or inter-valley areas. They carry considerable detritus from the upland, and plunge with a cascading rush down the escarpment of the main valley to the master stream. Much of their sediment is often deposited in alluvial fans, or cones, at the base of the valley wall, where the equilibrium between volume and load is abruptly broken. The residue, under a new adjustment, is strewn over the valley flood-plain or delivered to the main stream. The main stream is, therefore, for a part of the year essentially an aggrad-

ing rather than a degrading stream. The rest of the year the volume is extremely small, and the work accomplished proportionally slight. Such being the case the main stream, as at present constituted, is doing, and apparently has done, little work of vertical erosion.

In different parts of the valley, however, are remnants of well-developed terraces of destructional origin, which are out of all

FIG. 2.—Drift-covered floor of Catatonk Valley, N. Y.

proportion relative to present drainage conditions. The terraces are not continuous for any great distance, and often are entirely wanting on both sides of the valley. At some time during the preglacial period, and therefore previous to the deposition of drift, the valley was probably drained by two streams; one flowing to the north and one to the south from a common divide. In the lower half of the valley, as one proceeds from North Candor to Catatonk village, the valley grows gradually narrower, and a projection of the valley slopes intersect at a point much nearer the surface of the drift than toward the head of the valley,

although one is proceeding toward the mouth of the present stream, and where the greater maturity should be expected. Near the village of Catatonk the valley walls also reach their highest elevation—somewhat over 1,500 feet. North and south from this point the inclosing hills slope gradually away in both directions to an elevation approximating 1,300 feet. That is, the upland elevation opposite North Candor is about 1,360 feet, and opposite the present mouth of the stream, near Owego, the elevation is 1,280 feet; while between these two points the elevation exceeds 1,520 feet. If the surface contour of the upland represents the old preglacial topography, then the height of land must represent an original divide, over which the present stream is now flowing in a reversed course to the south.

The slope of the buried rock floor was obtainable only at two points, but shows that between Catatonk village and North Candor it is toward the north. The rock bottom, or preglacial floor, of the valley is thus deeply buried, and its grade and development do not necessarily coincide with that developed by the present stream over the surface of the drift filling.

In studying the probable history of the valley, relative to other adjacent valleys, and their bearing on the physiographic development of the region as a whole, the terraces furnished an additional suggestion as to a change that the drainage may have undergone. Professor W. M. Davis[1] has brought out many pertinent facts as to the origin, pattern, and preservation of river terraces. Many ideas there expressed were applied to the study of the Catatonk River terraces. It has been shown by Davis that the carving of destructional river terraces does not necessarily imply a greater power in a stream during past time and that the present stream is one of diminished volume. On the contrary, he points out that such features may be produced by stream-swinging and the migration of its meanders down stream, now on one side of the valley and now on the other, the volume remaining constant. Each return of the meander at a lower level would mark a terrace plain. A stream, unthwarted

[1] DAVIS, "River Terraces in New England," *Bull. Mus. Comp. Zool.*, Vol. XXXVIII (October, 1902).

in its work and excavating in homogeneous drift, might also on a return vibration undercut one or more terraces left by a previous shifting of its meanders. This would leave its vertical downcutting, or erosion, expressed in a high escarpment, which would represent the sum of later terrace scarps combined into a single scarp coincident with one of an earlier terrace.

Davis also calls attention to the fact that the preservation of a series of terraces is due to the dominant influence and controling power of buried ledges. These latter have the character of an upland spur projecting transversely out into the valley. A degrading stream in alluvial deposits, finding itself superimposed upon a transverse rock spur, would tend to migrate farther toward the axis of the valley, and thus slip by the obstruction, provided it was not so far incised laterally as to be held fast by the spur. The succeeding meanders, degrading having gone on, would return at a lower level and impinge upon the intercepting ledge still nearer the axis of the valley at each successive swing. On the other hand, a down-sweeping meander having encountered the buried ledge, and having a curvature above it well developed through deep lateral cutting, might be held fast by the projecting rock spur and unable to slip by. Succeeding meanders having advanced down stream, and their curvature above the ledge having been highly compressed, they would undercut and scour out former terracing by the enforced increase in the radius of its lateral cutting. This might continue until the meander became so compressed that it would eventually destroy itself by a cut-off, and allow the stream to pass the ledge by straightening its course. The presence of such spurs and buried ledges would defend and preserve on its immediate lee, or down-valley side, any terracing cut at an earlier period in the drift covering above it. Thus a salient of terraces would be preserved above the rock defended cusps.

The Catatonk River terraces do not lend themselves to such interpretations, either as being the work of a stream of constant volume, or their preservation being due to the intervention of a protecting spur (Fig. 3).

If we agree that the radius of a meander curve is limited and

proportional to a given stream flow, and when not interfered with will gradually bring itself to maturity, then the down-sweeping of an unobstructed meander must eventually result in its collapse and self-destruction through the medium of a cut-off. The present Catatonk River has obsolete meanders, now represented by more or less filled in cut-offs, or miniature oxbow lakes, that

FIG. 3.—Terraces along Catatonk River, N. Y.

seem to gauge the limit of its radius in meander development. The full extent of its present mature meanders and the shifting of the meander belt is much less than the opportunity offered by the flat bottom plain extending across the valley.

To whatever state of maturity the valley development had attained preglacially, it was directly modified by the advent of the glacial epoch. The old valley floor and its grade must have been somewhat affected by the southward movement and erosion of the first ice advance, and a probable lowering of the preglacial divide. Upon a subsequent retreat of the ice it was

aggraded by the fluvio-glacial débris. Later, the extra-morainic wash from the highly developed "kettle" morain, or the terminal morain of the second ice advance, lying only a few miles to the north, must have overwhelmed these intrenched valleys with floods of drift, under which their floors now lie deeply buried.

The proximity of the halted ice-front, and the immense load of detritus carried on, in, and beneath the ice, must have aggraded with tremendous rapidity the narrow valleys adjacent to it. The volume of drainage, fed by subglacial streams, by the general melting of the ice-front, by drainage from the land just released from the ice, and by the presumed greater precipitation of the glacial epoch, must have filled these valleys with streams of great volume, even after the continuity of the ice-sheet was broken by the melting upon hilltops and divides. Under such conditions it is not credible that the stream can be classed as one of either constant volume or load.

Drainage to the north was held in restraint by the blockage of the ice-front itself, and such conditions must have existed in north-sloping valleys as to transform them into temporarily ponded basins. The north-sloping valleys having become regions of more or less static water, the lower part (preglacially) of these valleys would be the points of greatest deposition. Helped in great measure by such aggrading and filling, the northward streams were compelled to flow over their former divides and adopt a southward outlet.

With the steady retreat of the ice two conditions of paramount importance must have been imposed upon the drainage: diminution in load, and a gradually diminishing volume. Both of these factors are of importance in the solution of these terraces, for a differential of either would affect the activity and scope of stream excavation. In the case in hand bold spurs do project into the valley flanked by terrace plains, but the interesting fact in regard to them is that the terraces appear on the *north* side, or up-valley, of the projecting spur, while the drainage flows to the south. It has been shown by Davis, both in text and by a variety of progressive illustrations, that terraces related to protecting spurs are removed by the stream on the up-

valley side, and only by the rarest chance are destroyed in the curve adjacent to the down-valley side. That these terraces are preserved with a south-flowing stream, upon the north side, or up-valley, would seem to indicate that there had been a north-flowing stream since the drift deposition of glacial time.

It is evident that there has been a reversal of drainage since the initial development of the valley in preglacial time, but the position of the terraces would indicate that they were due to the postglacial meandering of a north-flowing stream, and that their preservation was due to the superimposition of the stream on the projecting rock spur. That there has been a second reversal since the inception of the close of the glacial epoch, subsequent to the drift deposition, does not seem rational. Though a post-glacial uplift may have taken place, it does not appear from any analogous development in the region that it was of a sufficiently revolutionary character to bring about such a change.

As both the highest level terrace plain and the lowest part of the valley bottom are a homogeneous, assorted, and glacio-fluviatile drift, from one end of the valley to the other, the possibility that the terraces are remnants of a flood plain developed previously to the glacial epoch is not great. If they are the result of lateral swinging by a south-flowing stream, of constant volume, they should have been undercut and concentrated, or else distinctly modified by its successive meanders.

It is not essential to the solution to discuss in detail the various causes of reversed drainage, whether by headwater piracy, ice erosion, aggrading, or land tilting, nor the evidences of the same as expressed in the Catatonk Valley; but, so far as either the negative or the positive evidence of the terraces suggests anything, it tends to strengthen the belief that neither slope, load, nor volume has remained constant since the drift-filling and aggrading took place.

There is some additional evidence in the fact that the terrace fronts have a vastly greater arc of curvature than is developed by the swing of the present stream.

It seems likely from the fragmentary evidences that the valley was occupied, for a time subsequent to the withdrawal of the

ice, by a larger and more powerful south-flowing stream which had the potential of terrace-carving, either by diminished load or diminution of volume — possibly both. The accident of position and preservation is entirely independent of the presence of projecting spurs.

It is believed that an application of Davis's theories of terrace origin, pattern, and preservation, and their adaptation or non-adaptation to a given problem, may often afford suggestions as to the history of valley development by streams.

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SILURIAN AND DEVONIAN LIMESTONES OF WESTERN TENNESSEE.

(*Concluded from p. 583.*)

C. DEVONIAN STRATA IN THE TENNESSEE RIVER VALLEY.

11. *The Linden bed; Perryville, Linden, Horse Creek, Pyburn Bluff, White Sulphur Spring.*—About half a mile northeast of the railroad station at Perryville, a large quarry has been opened into the top of the Brownsport bed. Immediately above is found the base of the Linden limestone, with *Orthothetes woolworthanus*, *Rhipidomella oblata*, and *Striatopora issa*. The lower third of the Linden bed, 10½ feet thick, consists of fairly solid crinoidal rock with comparatively few fossils. The middle third, 11½ feet thick, is richly fossiliferous. It consists of softer rock, partly crinoidal, partly fine-grained, and more or less interbedded with clay. At the base of this middle division, *Stropheodonto beckei*, *Strophonella punctulifera*, and *Orthothetes woolworthanus* are common. *Dalmanites micrurus* is not rare, but *Uncinulus schucherti* is very scarce. Above this *Stropheodonta beckei* horizon the limestones and especially the more weathered beds and clays are full of the smaller brachiopods identified from the Linden bed at Perryville. The upper third of the Linden bed, about 15 feet thick, consists of fossiliferous clay. It is exposed in the northwestern corner of the town, and is overlaid by thin layers of limestone, full of bryozoans, forming a section 1½ feet thick, followed by a sandy bed which may be the Hardin sandstone. The Camden chert fossils found at Perryville occurred loose, and were apparently derived from the iron-ore gravels of Safford.

A mile north of Linden, above the spring north of the home of William H. Patton, the Brownsport bed is overlaid by solid massive limestone, 5⅓ feet thick, containing few fossils; more shaly beds, 7⅔ feet thick, containing the characteristic Linden bed fauna; clayey beds, 6½ feet thick, not exposed; a total of 20 feet referred to the Linden bed. Above this occurs

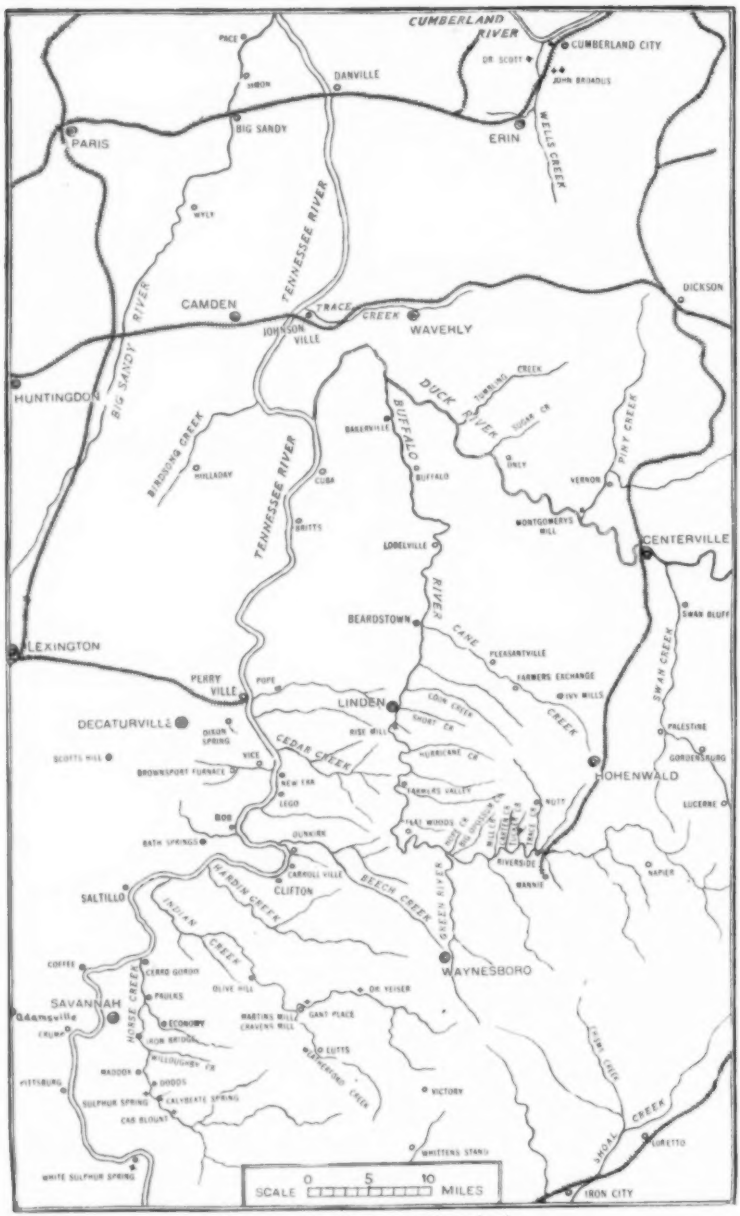

FIG. 7.—The Tennessee River basin.

(The name *Dunkirk* on the map should be read *Glenkirk*).

the Hardin sandstone, 1 foot thick, and the Black shale, 6½ feet thick. The fossiliferous part of the Linden bed is well exposed also about half a mile northeast of this locality, in the woods.

The Linden bed is exposed also on the eastern edge of Linden, below the level of the town spring at the foot of the hill, and thence eastward along the upper edge of the low bluff bordering the stream flowing from the spring toward the Buffalo River. The thickness of the Linden bed at this point is about 11 feet. Overlying it is a more massive rock, 2 feet thick, referred to the Camden chert; followed by the Hardin sandstone, 18 inches thick, and the Black shale, 6 feet thick, with numerous phosphatic nodules at the top.

About a mile east of Linden, on Short Creek, a quarter of a mile west of the home of J. S. Journey, the Linden bed is 11 feet thick. It is overlaid by the Hardin sandstone, 2 feet thick, followed by the Black shale.

The Linden limestone evidently thins out rapidly eastward. Half a mile east of the exposure west of the home of J. S. Journey, at the top of a bluff rising above a spring along Short Creek, east of the mouth of Jacks Branch, the Brownsport bed is directly overlaid by the Hardin sandstone, 2 feet thick, Black shale, 2 feet thick, and bluish sandy rock, 3 inches thick. No Linden rock is found at the home of William Goodwin on Coon Creek, 2¼ miles northeast of Linden, or at the Webb or Rise mill, half a mile south of Linden. It evidently thins out also southward, since it is absent northeast of Lego, along a creek also known as Short Creek. It is absent along the upper part of the Buffalo River between Flat Woods and Riverside, and along the upper part of Indian Creek above Olive Hill.

From the limited evidence so far secured it appears that the eastern line of outcrop of the Linden bed passes between Linden and the Rise mill, and then turns westward, crossing the Tennessee River somewhere north of Lego. There is no evidence of the presence of the Linden bed in the area between Brownsport Furnace and Bath Springs. It is possible that the eastern line of outcrop does not recross the Tennessee River north of the mouth of Horse Creek. The Linden bed is absent along

the Headwaters of Indian Creek, but is present along the headwaters of Horse Creek. The chief difficulty encountered in attempting to trace the eastern line of outcrop of the Linden bed is the absence of exposures at the proper horizon in most of the territory contiguous to the Tennessee River, due to removal of the upper part of the Silurian section and of the overlying

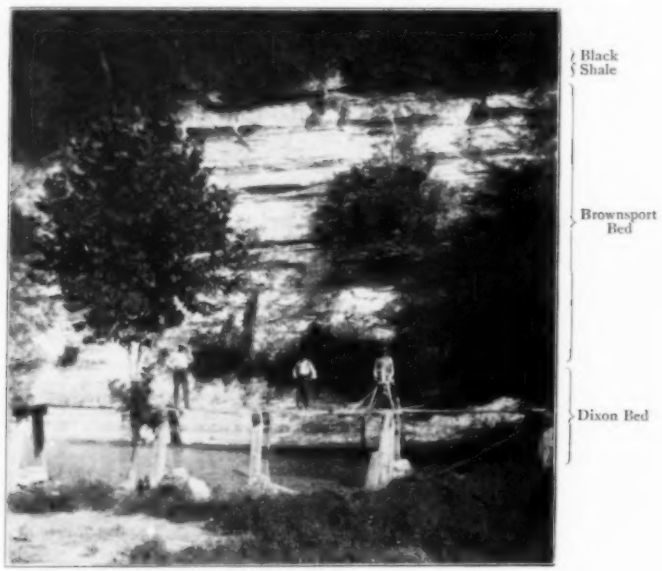

FIG. 8.—Bluff at Rise Mill.

paleozoic rocks by Cretaceous and Tertiary erosion. At most localities within this territory the Silurian rocks are directly overlaid by the Coffee sand or by the iron bearing gravels of Professor Safford.

The Linden limestone is well exposed at the Calybeate Spring on Horse Creek. Over a mile south of Maddox store, a road leaves the Florence road and passes through the woods eastward to the Sulphur Spring. Skirting the northern side of a large corn field, it crosses Horse Creek and follows the eastern bank for more than a mile, during the latter part of the distance along

the upper edge of a low bluff, ending at a cultivated field at the mouth of a stream traversing a narrow valley. The base of the bluff on the east side of Horse Creek, just north of the mouth of this stream, is formed by crinoidal, massive limestone, apparently belonging to the top of the Brownsport bed. Immediately above is limestone and clayey rock containing, within 10 feet of the base, *Camarocrinus* and a number of brachiopods belonging to the Linden bed fauna. Among these are *Dalmanella subcarinata*, two forms, one coarsely and one finely striate, *Rhipidomella oblata*, *Bilobites varica*, *Strophonella punctulifera*, and *Spirifer perlamellosus*. About 200 yards south of the locality just described, on the same side of Horse Creek, is the Calybeate Spring. Here the exposure of the Linden bed is at least 60 feet thick. Specimens of *Camarocrinus* are abundant in the lower and middle part. Two miles above the Calybeate Spring, in a gulley southeast of the home of Cab Blount, on the east side of a branch of Horse Creek, the Linden bed is overlaid by a trace of Black shale, poorly exposed, followed by the Waverly. Within 10 feet of the top of the Linden bed it contains specimens of *Camarocrinus*.

Large exposures of the Linden bed line the northern side of the Tennessee River for more than a mile east of Pyburn Landing. Here was obtained the section described by Safford as occurring opposite White Sulphur Spring. At the eastern end of the exposures, west of the mouth of Bluff Creek, the exposure of the Linden bed is 101 feet thick. At the base of the section there is a series of cherty limestones, 11 feet thick, containing a species of *Chonostrophia* 23 mm wide related to *Ch. helderbergia*, *Rhipidomella oblata*, *Uncinulus nucleolatus*, *Uncinulus* (*Wilsonia?*) *schucherti*, *Meristella meeki*, and *Dalmanites pleuroptyx*. Unequal erosion of the cherty limestone forming the Linden bed has caused the formation of shelves at elevations of 11, 34, and 50 feet above the river. *Camarocrinus* occurs from the water's edge up to the 50 foot level. At the top of this part of the section, *Camarocrinus* is associated with *Favosites conicus*, *Favosites* with a convex base covered by the epitheca, *Pleurodictyum lenticulare*, *Rhipidomella oblata*, *Orthothetes woolworthanus*, *Leptaena*

rhomboidalis, Strophcodonta beckei, Strophonella punctulifera, Uncinulus nucleolatus, Atrypa reticularis, Delthyris perlamellosus, Delthyris related to *D. perlamellosus*, but with a large, high, flat, triangular area on the ventral valve, *Spirifer cyclopterus, Spirifer* with 3 or 4 plications on either side of the mesial fold, ornamented with fine radiating striae, evidently closely related to or identical with *Spirifer tenuistriatus, Meristella meeki, Platyceras tenuiliratum*, and *Dalmanites pleuroptyx*.

No specimens of *Camarocrinus* were found above the 50-foot level, but the Linden fauna continues into the overlying rocks. It is abundantly represented in two cherty layers which immediately overlie the *Camarocrinus* beds, and in a layer of chert, about 1 foot thick, which occurs about 19 feet above the *Camarocrinus* beds. A large part of the section above the *Camarocrinus* horizon is soft and weathers readily, usually forming poor exposures, but the top of the Linden section at this locality is formed by more massive limestone, 17 feet thick, containing few fossils. Among these is *Dalmanites pleuroptyx*. The Black shale series is absent. The basal layer of the Waverly is 20 inches thick, and consists of sandy shaly rock belonging to the Hardin sandstone, and containing large specimens of *Spirophyton*.

The Linden bed dips westward; that part of the bed exposed in the eastern bluff apparently dips beneath the rock forming the western bluff, west of Anderson and Johnson branches. A study of the western bluff, however, suggests that the section here exposed is merely a repetition of the eastern section, just described. The massive limestone at the top of the Linden bed, however, has a thickness of only 6 to 10 feet, being unconformably overlaid by the Black shale series. It contains *Rhipidomella oblata, Spirifer cyclopterus, Uncinulus nucleolatus, Meristella princeps, Platyceras tenuiliratum, Dalmanites pleuroptyx*, and *Phacops logani*.

West of the store at White Sulphur Spring, 1 ½ miles southwest of Pickwick Landing, numerous Linden bed fossils occur in the residual chert along the middle and lower parts of the hillside. Exposures occur also in the vicinity of Decaturville, at Hollady, 5 miles south of Big Sandy station on the Lower Cam-

den road, and at other points along the Big Sandy River. The Linden bed is exposed along the Cumberland River, a mile west of Cumberland City, and on the eastern side of the railroad, a quarter of a mile south of the home of John Broadus. Owing to faulting, it is impossible to determine the thickness of the Linden bed in the Wells Creek basin, but, as far as may be judged from the exposures seen, it does not exceed 30 feet. East of the home of John Broadus the exposure of the Linden bed does not exceed 10 or 15 feet. Mr. Charles Schuchert found three specimens of *Camarocrinus* in Benton county at an undetermined horizon.

As far as may be judged from the few sections so far studied, *Camarocrinus* is abundant in the lower half of the Linden bed, and is either much rarer or altogether absent in the upper half. The upper half, on the contrary, appears to contain a greater quantity of softer, clayey material, which weathers readily. It appears to give rise to the greater number of exposures at which the Linden bed fossils may be collected free from the rock. It appears possible to divide the Linden bed into two subdivisions, a lower, Camarocrinus or *Ross limestone*, and an upper, or *Pyburn limestone*. The exposures at Perryville, Linden, and Cumberland City appear to belong to the upper or Pyburn horizon. The upper bed appears to have a greater eastward extension than the lower, overlapping the latter. Very little attention has been given so far to the stratigraphy of the Devonian in western Tennessee. The chief results of the writer's efforts have been the conclusion that the Linden bed is absent in a large part of the territory east of the Tennessee River once believed to contain it. It is not known to occur anywhere between Rise mill, New Era, Bath Springs, Economy, and Martin's mill.

12. *The Camden chert.*—As in the case of the Linden bed, the thickest sections of the Camden chert are found at the more western points of outcrop. At Linden, on the eastern edge of the town, at the spring near the foot of the hill, it is represented by a massive gritty limestone, only 2 feet thick, immediately beneath the Hardin sandstone. In this rock were found two ventral valves of *Spirifer*, silicified, showing both the exterior and also the large muscular scars in the interior. They were identi-

fied by Schuchert as *Spirifer murchisoni*, a lower variety of *Spirifer arrectus*. They are evidently foreign to the Linden bed, and require the identification of the gritty limestone as part of the Camden chert series.

At Perryville, two silicified specimens of *Eatonia peculiaris*, and a single specimen of a large form of *Camarotoechia* (40^{mm} long, 36^{mm} wide, and 28^{mm} thick) belonging to the group of *Camarotoechia pleiopleura*, were obtained loose at the base of the sand and gravel overlying the Linden bed at the quarry. If the identification of the Hardin sandstone in the northwestern corner of Perryville is correct, the Camden chert bed can not exceed 2 or 3 feet at this locality, and it is probably altogether absent. It probably occurs, however, a short distance farther north. It is said, by Professor Safford, to occur in Decatur county, but it has not yet been recognized farther southward, in any part of Hardin county. The typical exposures occur at Camden, where the section is at least 60 feet thick. Five miles south of Big Sandy station, on the lower Camden road, the base of the Camden chert is said by Professor Safford to rest upon the Lower Helderberg. The writer has not seen any locality where it is possible to draw any sharp line between these formations. Lithologically, the formations are alike, and paleontologically, the change from the Linden bed fauna to the Camden chert fauna appears to be gradual rather than abrupt.

The chert derived from the Camden chert appears on the hillsides for several miles south of Big Sandy station. At the old Williams mill site, 5 miles above the mouth of Big Sandy station, there is a large exposure of the Camden chert bed. The thickness of the bed must be considerably in excess of 50 feet.

About 4 miles north of Bakerville, at the Whirl in the Buffalo River, the top of the Camden chert rises nearly 50 feet above the river. The exposure may be reached most conveniently by turning off from the Waverly road at the home of Clinton Burcham, following the lane along the northern edge of the hill for half a mile to the home of Henry McClure, and then crossing the field southeastward to the river bluff. The upper layers contain *Eatonia peculiaris*, *Amphigenia curta*, *Anoplotheca flabellites*, and a

Rhipidomella resembling *Rhipidomella oblata*. Two species of *Spirifer* occur which are related apparently to *Spirifer unicus* and *Spirifer arrectus*. The typical Upper Oriskany, characteristic of the Oriskany sandstone of the Appalachian region, does not occur, but a part of the Camden chert appears to belong to a higher horizon at least than at first supposed. A single specimen of *Edriocrinus* was found.

The same species of *Edriocrinus* occurs near the western end of the exposures along the Cumberland River, west of Cumberland City; on the eastern side of the railroad, a quarter of a mile south of the home of John Broadus; and on the rocky face of the hill southeast of the home of Christopher Schmidt, about a mile south of the home of Dr. Scott. At the western end of the exposures along the Cumberland River Professor Safford identified the top of the limestone section as belonging to the Camden horizon. The writer was not able to verify this in the short time at his command. No specimens of the species of *Edriocrinus* in question were found in the undoubted Linden bed exposures farther southward, but the genus is known to occur also in the Helderbergian elsewhere, although the species in question may have a more limited range.

13. *The Onondaga limestone.*—On the western flank of the Cincinnati geanticline, along the Harpeth River, between Newsom and the bridge west of Pegram, the Silurian is directly overlaid by a thin bed of Devonian limestone,[1] varying in thickness from 12 feet at the west to 3 feet at the most eastern point of outcrop. West of Pegram, at the bridge, it rests upon the soft clay forming the lowest part of the Brownsport bed. At Newsom, at the most eastern point of outcrop, it is underlaid by the equivalent of the Lego bed, 32 feet thick. *Nucleocrinus* (*Olivanites*) *verneuili*, is a characteristic species. *Stropheodonta demissa*, *Stropheodonta perplana* *Rhipidomella penelope*, and *Nucleospira concinna* are also found. This white and comparatively pure limestone is overlaid by a darker and more sandy limestone containing small grains or concretions of some black substance, similar to the black particles found

[1] Silurian and Devonian limestones of Tennessee and Kentucky, *Bull. Geol. Soc. Amer.*, Vol. XII, 1901.

in the beds containing fish-teeth in the Devonian of Kentucky and Indiana.

At the Whirl, 4 miles north of Bakerville, at the west end of the bluff exposing the Camden bed, there is a cultivated field. Almost directly east of the well and stable in the center of this field, near the lower part of the hillside, Devonian corals are very abundant. Species of *Heliophyllum*, and *Blothrophyllum* occur which closely resemble forms occurring in the Corniferous at the Falls of the Ohio River, at Louisville, Ky. Various species of *Cystiphyllum*, *Cyathophyllum*, and *Cladopora* also are found. In addition to a very large form of *Atrypa reticularis*, a single specimen of *Reticularia fimbriata* was present. The corals have been loosened by residual decay from a bed of limestone, about 3 feet thick. The top of this layer is formed by a darker, sandy layer, varying from a mere film to a little over 2 inches in thickness. This darker part resembles the darker layer at the top of the Devonian limestone section at the bridge west of Pegram. It contained a single, pointed fish bone, 45^{mm} long. This bed of limestone, 3 feet thick, is believed to be of about the same age as the Devonian limestone at Pegram. Both limestones are correlated with the Jeffersonville limestone of Kentucky and Indiana, which is the equivalent of the Corniferous or Onondaga limestone of more eastern sections.

The occurrence of the Onondaga limestone near Bakerville suggests that it may be expected at other localities in western Tennessee northwest of a line passing from Bakerville to Lexington.

14. *The Devonian Black shale series.*—The Chattanooga Black shale decreases in thickness from the north central part of the state southward and westward. Its thickness in the neighborhood of Cumberland City cannot be determined with accuracy, but it appears to reach at least 10 feet. At Montgomery's mill the shale has a thickness of 6 feet 3 inches; at Centreville, of 4 feet 6 inches; at Dean's quarry, of 2 feet. In the neighborhood of Linden the thickness varies between 1 and 6½ feet; at several exposures east of Linden a thin layer of sandy rock occurs in the shale, about 1 foot above its base. Along the Buffalo River it is

usually absent; one exposure, 1 foot thick, occurs on Tucker branch, and another, 2 feet thick, several miles west of the mouth of Green River. A trace of Black shale, not well exposed, was seen in a gully on the west side of Horse Creek, southeast of the home of Cab Blount. It is absent at Pyburn Bluff, opposite White Sulphur Spring. Five miles southwest of Mount Pleasant, at the Big Hill on the road to Waynesboro, the Black slate is absent, but a mile southeast of the hill it attains a thickness of 2 feet. At Dodson station and at Lynnville, 15 miles southeast of Mount Pleasant, it does not exceed 15 inches. At Iron City it varies from 6 inches to nothing.

From these and many other observations it may be seen that the Black shale is either very thin or is entirely absent in the southern parts of Maury, Lewis, and Perry counties, and in all of Giles, Lawrence, Wayne, and Hardin counties.

The Black shale occurs also on the western side of the Tennessee River. It was struck in digging a well north of the landing at Saltillo. A considerable quantity of Black shale was struck northwest of the furnace at Brownsport Furnace. A small exposure occurs near the bottom of a broad valley along the road half-way between Dixon Spring and Perryville. It probably occurs at other localities farther north. The scarcity of exposures is probably chiefly due to removal by erosion during Cretaceous and Tertiary times, the sands and gravels of these ages resting directly on Helderbergian and Silurian rocks in a large part of the area so far investigated.

At the more northern exposures the Black shale is usually underlaid by a sandy rock, 1 or 2 feet thick, and overlaid by another layer, usually only several inches thick, characterized by the presence of phosphatic nodules. Southward the sandy layer becomes thicker, developing into the *Hardin sandstone*. Owing to the thinning out of the Black shale in this direction, the *nodule layer* not infrequently rests directly on the Hardin sandstone. This is shown at a number of exposures along the upper part of the Buffalo River, between Riverside and Flatwoods. Farther south the phosphatic nodule layer is also usually absent, so that in the southern counties the Hardin sand-

stone is often the only representative of the Black shale group. The most southern localities at which phosphatic nodules were observed were at W. D. Holton's home, 3½ miles northwest of Waynesboro, and at the Taylor quarry near Iron City.

The Hardin sandstone frequently attains a thickness of 7 to 8 feet. The greatest thickness observed was 11 feet. About a mile northwest of Martin's mill, on Indian Creek, a fish plate, 4 inches long, was observed imbedded in this sandstone. At several localities *Barroisella subspatulata* was seen in the more shaley layers immediately above the Hardin sandstone. These layers form a transition to the Waverly, the Lauderdale cherty beds of the Alabama Survey. The eastward extension of the Hardin sandstone has not yet been determined.

D. SILURIAN AND DEVONIAN STRATA OF THE WELLS CREEK BASIN.

The Wells Creek Valley, southwest of Cumberland City on the lower part of the Cumberland River in western Tennessee, is 53 miles distant from Baker station, and 45 miles from Whites Bend, Newsom, and Centreville. Both lithologically and faunally the Silurian of the Wells Creek valley presents the facies of the Silurian of the Tennessee River valley rather than the appearance of the Silurian exposed on the western flank of the Cincinnati anticline.

About 3 miles southwest of Cumberland City, in a railroad cut northwest of the home of John Broadus, there is a considerable exposure of Ordovician rock, probably equivalent to the Saltillo limestone, originally consisting of frequent alternations of clay and clayey limestone, but now badly decayed and reduced in large part to shaly material. Owing to a local, overturned fold, the Silurian base is found south of the Ordovician exposure and apparently dipping beneath it. The base of the Silurian section consists of hard limestone, much faulted, estimated to be 22 feet thick. The lower half is massive and contains *Favosites favosus*. The upper half contains cherty layers. Next in order of succession is a red, clayey rock, also faulted, estimated to be 14 feet thick. At its base it is more whitish. At the top it grades into limestone, 7 feet thick, less red and clayey above, containing

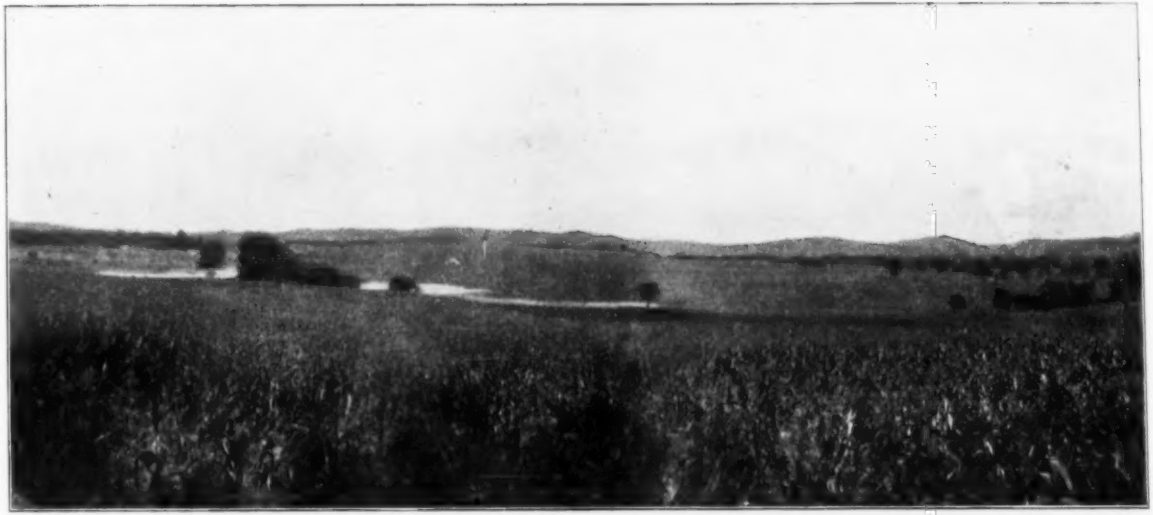

FIG. 9.—View from home of Dr. W. B. Scott, east across the Wells Creek basin, showing the dome structure. The central area is the region of the Wells limestone. The water in the foreground, due to recent heavy rains, and the line of trees circling from the right across the background, indicates in a general way the location of the Saltillo limestone. Along the foot of the hills bordering the basin, Silurian and Devonian rocks are exposed. The upper part of the hills and the surrounding country consists of sub-carboniferous rocks.

Stephanocrinus osgoodensis and *Pisocrinus gemmiformis*. The red clay and reddish limestone is the equivalent of the Osgood bed as identified at Clifton and elsewhere, and the white limestone at the base of the Silurian section corresponds to the Clinton.

Next in order of succession is slightly crinoidal limestone, 2 feet thick, followed by reddish clay, 3 feet thick. Stratigraphically above this horizon belongs the crackled white and reddish limestone, the equivalent of the Glenkirk bed. Owing to the failure to identify the Waldron bed, the subdivisions of the Glenkirk bed, the Laurel and Lego limestones, cannot be recognized. This difficulty is increased by a considerable amount of very irregular faulting. Along the road east of the home of John Broadus the top of the Glenkirk bed is well exposed. It is overlaid by dark, brick-red clay rock, 32 feet thick, belonging to the Dixon bed. This is followed by a section 20 feet thick, not exposed. The overlying Brownsport bed dips strongly eastward. If not faulted, the section is 170 feet thick, but faulting is not improbable. *Astraeospongia meniscus* occurs near the base. At the top of the section a thin layer of fossiliferous limestone belonging to the Linden bed, is exposed. In a gully, southeastward, Black slate is exposed.

Along the railroad, a quarter of a mile south of the home of John Broadus, there is a considerable exposure of limestone. A part of it contains *Edriocrinus*. At the southern end of the exposure is a richly fossiliferous layer, apparently belonging to the Linden bed.

In the field south of the home of Dr. Scott, the layers at the top of the Osgood bed, containing *Pisocrinus gemmiformis*, and *Stephanocrinus osgoodensis* are found. Along the road southwest of the house and in the cedar glade west of the same, brachiopods and sponges belonging to the Brownsport horizon occur. About a quarter of a mile north of the house, along the road following the base of the hill, the Glenkirk bed is well exposed. A part of the Glenkirk exposure consists of a very hard and fine-grained, massive, red limestone. Another part is softer and white, followed by the red clayey rock belonging to the Dixon bed, well exposed. The Linden bed was not identified at this

locality. About a mile southward, on a rocky hillside south of the home of Christopher Schmidt, *Edriocrinus* occurs in the limestone.

Along the Cumberland River, about a mile west of Cumberland City, a short distance beyond the exposures which line the bank, Black shale is exposed above the level of the road. At

FIG. 10.— Saltillo limestone, at crossing of pike from Cumberland City to Erin over the railroad.

the western end of the rock exposures along the bank, just below the level of the road, the Linden bed fossils are abundant. It is possible that some of the overlying limestones belong to the Camden chert horizon but the writer was not able to identify it in the short time at his disposal. The red rock forming the greater part of the exposures along the bank eastward toward Cumberland City appears lithologically to belong to the Glenkirk horizon. Faulting appears to be very frequent, bringing into contact all sorts of rocks, making stratigraphic work difficult. However, even a hasty examination of the field is sufficient to

determine the fact that in all essentials the Silurian and Devonian sections of the Wells Creek basin strongly resemble those of the Tennessee River valley.

E. THE EQUIVALENCE OF THE CLIFTON, LINDEN, AND CAMDEN LIMESTONES TO OTHER BEDS.

In the *Geology of Tennessee*, published in 1869, Professor Safford included all Niagaran strata, from the Clinton bed to the Brownsport bed, inclusive, in his *Meniscus limestone*. He recognized, however, two subdivisions, each about 100 feet thick, the lower called the *Variegated bed*, the upper called the *Sponge-bearing bed*. The Variegated bed included the Clinton, Osgood, Laurel, Waldron, and Dixon beds of the present paper. The Sponge-bearing bed included the Brownsport bed. *Astraeospongia meniscus* is confined to the upper or Sponge-bearing bed.

In the *Elementary Geology of Tennessee*, published in 1876, Safford and Killebrew proposed the name *Clifton limestone* for the Meniscus limestone. This name is, therefore, equivalent to the name "Niagaran" as now defined.

At Clifton, the type locality, the section along the river below the landing includes the Clinton, Osgood, and Laurel limestones. The section along the river about three-quarters of a mile above the landing includes the upper part of the Laurel bed, the Waldron, Lego, and Dixon beds, and the greater part of the Brownsport bed. Immediately in the rear of the town, on the hillside north of the Waynesboro road, the upper part of the Lego bed, all of the Dixon red clay, and the base of the Brownsport bed are exposed.

As a synonym for the Niagaran, the name "Clifton limestone" will be found useful.

In the *Geology of Tennessee*, all strata in western Tennessee intervening between the Clifton bed and the Chattanooga black shale were included in the Lower Helderberg. In 1876, in the *Elementary Geology*, Safford and Killebrew employed the name *Linden limestone* for these strata. In 1899 Safford and Shuchert published an article in the *American Journal of Science*, entitled "The Camden Chert of Tennessee and its Lower Oriskany

Fauna," in which the Oriskany age of the upper part of the beds hitherto included in the Linden bed was shown. Therefore, in 1900, in a second edition of the *Geology of Tennessee*, Safford and Killebrew restricted the use of the name "Linden limestone" so as to include only beds belonging to the Helderbergian as now defined, while the name "Camden chert" was given to the Oriskanian strata formerly included in the upper part of the Linden limestone. The Linden limestone as now defined appears most nearly equivalent to the Delthyris or New Scotland bed.

The Camden chert was placed by Schuchert in the lower part of the Oriskanian. He called attention particularly to the absence of the characteristic upper Oriskanian species: *Hipparionyx proximus*, *Chonostrophia complanata*, *Spirifer arenosus*, *Rensselaeria ovoides*, *Meristella lata*, *Camarotoechia pleiopleura*, *C. barrandei*, and *C. speciosus*. Since his paper appeared a specimen related to *C. pleiopleura* was found loose in the sand above the Linden bed at Perryville, and a *Spirifer* resembling *Spirifer unicus* was found in the top of the Camden bed at the Whirl in the Buffalo River north of Bakerville.

The use of the name "Linden limestone" for the Helderbergian section in Tennessee is unfortunate, since at the type locality, Linden, the Helderbergian does not exceed 17 feet in thickness, while the maximum thickness in the state exceeds 100 feet. Moreover, the Helderbergian at Linden is overlaid by a thin section of Camden chert, 2 feet thick, hitherto included in the Linden bed. The Linden bed at Linden apparently belongs to the upper, more clayey part of the Helderbergian section as exposed in Tennessee, overlying the *Camarocrinus* beds. However, too little attention has been given as yet to the stratigraphy of the Devonian limestones of Tennessee to warrant a definite conclusion.

F. THE COFFEE SAND.

At various localities along the Tennessee River, in Hardin county, the paleozoic formations are overlaid by yellowish sands, sometimes interstratified with beds of clay. They have been called the Coffee sand by Professor Safford, and are believed to be equivalent to the Tombigbee sand, referred to the Lower

Cretaceous. The exposure at Coffee Landing is typical for the Tennessee beds. Silicified trunks of trees are not uncommon. One, 6 feet long and 2 feet in diameter, occurred in the sand directly above the Glenkirk limestone at the Welch or Maddox mill on Horse Creek. Another was found near Lutts, beyond the post-office, on the road to Waterloo. The locality is called Pin Hook Hill, and lies between Rutherford and Horse Creeks. A third trunk is seen on the Jack Martin farm, about seven miles north of Cypress Inn and five miles south of Victory, on the headwaters of Weatherford fork of Indian Creek. The trunk is found in the hollow in the field below the Martin house. The locality is fully twenty miles east of the Tennessee River. It has been suggested that the Gulf of Mexico once extended much farther north than at present, reaching the southern part of Illinois and covering southeastern Missouri. If the Coffee sand was deposited off its shores, the Gulf, during early Cretaceous times, must have extended east of the Tennessee River, at least in the southern part of Tennessee, in parts of Wayne and Hardin counties.

G. THE IRON ORE GRAVELS.

In western Tennessee, in the area lying between the Great Central Basin and the Tennessee River, the paleozoic rocks are usually overlaid by a great mass of sands and gravels, often cemented by ferruginous material. Sometimes the ferruginous material is in sufficient quantity to prove valuable as an iron ore. Thirty-five furnaces were in operation before the war, and the ore is still mined at a number of localities. The branches of railroad from Dickson to Mannie, from Summertown to Napier, and from Iron City to Pinckney owe their existence to the presence, at their terminals and at various points along the line, of ferruginous gravels, sufficiently rich in iron ore to be mined. The large furnaces at Florence and Sheffield in Alabama partly depend upon this source. The ferruginous iron-ore gravels extend west of the Tennessee River for a distance of ten or fifteen miles, resting upon the paleozoic rocks on all the higher hills. At lower levels, where the paleozoic rocks are covered by the Coffee sand, the iron-ore gravels rest upon the Coffee sand.

Along Horse Creek, the Ordovician and Silurian rocks have been reduced by Cretaceous erosion to a sort of base level and then covered by the Coffee sand. The Helderbergian exposures at the Calybeate Springs appear to have risen above the level of the Coffee sand (Fig. 3, p. 579). No careful study of the Coffee sand or of the iron-ore gravels has yet been made in the area in question.

II. THE AGE OF THE CINCINNATI GEANTICLINE.

15. *As determined by observations in Tennessee.*—Along the Cincinnati geanticline in Tennessee the Chattanooga black shale rests unconformably on Silurian and Ordovician rocks. Along the crest of the geanticline, for a width of 55 to 75 miles, the Black shale, where not removed by subsequent erosion, rests upon Ordovician strata. On either side of this area it rests upon the Silurian. Along the eastern line of outcrop of the Silurian, on the western flank of the geanticline, the Black shale rests upon the Clinton. Farther westward, proceeding to points more distant from the broad crest of the geanticline, the Black shale rests successively upon the Osgood, Laurel, Waldron, and Louisville beds, the higher subdivisions of the Silurian. On proceeding still farther westward, into the basin of the Tennessee River, this unconformity continues, so that the Black shale rests upon higher Silurian rocks in the Tennessee River valley than at Pegram, Centreville, Riverside, or Iron City. It rests upon higher layers of the Brownsport bed along the Tennessee River than at the more eastern exposures of this bed. East of Linden the Black shale rests upon the attenuated edge of the Linden bed. At Linden it rests upon the still more attenuated edge of the Camden chert. West of the Tennessee River both the Linden and the Camden beds are represented by thicker sections.

The Tennessee River region may be regarded as having formed, in times preceding the deposition of the Black shale, a broad geosyncline of Silurian and Devonian limestones, lying west of a broad geanticline of Ordovician strata. The axis of the geosyncline lay a considerable distance west of the Tennessee River. Both lithologically and paleontologically the Silu-

rian deposits of the geosyncline differ sufficiently from those of the geanticline to form a distinct province. The Silurian deposits of the geosyncline extended northward into southern Illinois and the adjacent part of Missouri. The formation of this geosyncline was the first expression of the series of changes which finally resulted in the formation of the lower Mississippi valley.

Mesodevonic limestones are but scantily represented in the Tennessee River valley. At the Whirl in the Buffalo River, 4 miles north of Bakerville, they are 3 feet thick. Forty-five miles farther east, along the Harpeth River, they vary in thickness between 3 and 12 feet. At both localities, the Mesodevonic limestones belong to the Onondaga horizon. At Newsom, the Onondaga limestones rests on the equivalent of the Lego bed; at Pegram, on the lower part of the Brownsport bed; and north of Bakerville, on the Camden chert bed. The unconformity thus indicated suggests the existence of the Cincinnati geanticline in times preceding the Mesodevonic.

The Paleodevonic is absent along the western flank of the Cincinnati geanticline, in Tennessee, Kentucky, and southern Indiana. It is exposed, however, at numerous points in the Tennessee River valley, especially west of the Tennessee River. Both the Oriskanian and the Helderbergian are represented. Where more fully developed, the passage from the Helderbergian to the Oriskanian appears to be gradual, not indicating any unconformity between them. At their attenuated margins near Linden, the line of demarkation between the beds is very distinct. This suggests the growth of the Cincinnati geanticline during the Paleodevonic times.

Very few localities have so far been discovered where the contact between the Helderbergian and the Silurian may be studied. At all of these localities the Linden bed rests upon the Brownsport bed, and the change from the Silurian to the Devonian fauna is abrupt. It is impossible to determine at present whether the Linden bed rests upon higher horizons of the Brownsport bed westward than along the eastern line of outcrop. The faunus of the Brownsport have not yet been studied in sufficient detail to warrant any conclusions at present. If the

Linden bed fauna at Linden is the equivalent of the upper or Pyburn fauna at Pyburn Bluff, and overlies, stratigraphically, the lower or Camarocrinus fauna at that bluff, then the upper part of the Linden bed overlaps the lower part; suggesting the growth of the Cincinnati geanticline during the earlier part of the Paleodevonic. The studies so far made upon the Linden bed are insufficient to determine the matter.

No trace of the Upper Silurian or Cayugan has so far been discovered in the Tennessee River valley or in the Mississippi River basin.

From these observations it appears that the growth of the Cincinnati geanticline began in times preceding the Devonian, that its growth continued during early and middle Devonian times, and that it had reached considerable proportions in times preceding the deposition of the Chattanooga black shale.

The stratigraphic evidence secured so far is not sufficient to demonstrate the existence of the Cincinnati geanticline in Ordovician times. However, a study of the areal distribution of Silurian and Ordovician faunas suggests that the Cincinnati geanticline had its origin during Ordovician times, and that its effect upon the geographic range of faunas was considerable already during the earlier part of the Silurian[1] This method of determining the location of geologic barriers by means of a study of the distribution of faunas promises to be of the highest value, since it appears capable of demonstrating the existence and probable location of barriers even in cases where the stratigraphic evidence is defective, although, of course, it is eminently desirable that the results of paleontological research be corroborated by stratigraphical evidence.

Data are accumulating which suggest the existence of an elevation of land, or dome, in southwestern Tennessee during the later part of the Ordovician and at the beginning of the Silurian. According to the researches of Ulrich and Bassler, the Utica is absent in central and southern Tennessee; the Lorraine, however, is represented by equivalents of the Fairmount, Bellevue,

[1] ULRICH AND SCHUCHERT, "Paleozoic Seas and Barriers," *Report of New York Paleontologist* for 1901, No. 2.

and Corryville beds[1] of the Cincinnati section. The Utica is absent also in western Tennessee. The Swan Creek limestone is undoubtedly of Lorraine age; and analogy with the sections in central Tennessee, investigated by Ulrich and Bassler, suggests that the richly fossiliferous beds, containing *Platystrophia lynx*, below the Swan Creek limestone are probably equivalent to the Bellevue beds. No trace of the Fairmount, Bellevue, or Corryville beds has been recognized in western Tennessee, in the Tennessee River basin. This suggests a more rapid depression of the land eastward, permitting the invasion of the Lorraine sea, while in the Tennessee River basin no deposits belonging to the three horizons named are present. Moreover, the Richmond, although extending further southward and westward, is absent at Swallow Bluff, apparently also at Saltillo, and only a trace of Richmond clay, several inches thick, was found along Horse Creek, at Maddox mill. Again, the Clinton, which has a considerable development north, west, and southwest of Nashville, and which presents thick sections even as far south as Centreville and the Swan Creek valley, is less than 4 feet thick at Glenkirk, is 2 feet thick at Swallow Bluff, does not exceed 1 foot in thickness at Clifton, Riverside, and Iron City, is possibly represented by a few inches of decayed ferruginous material at the base of the Silurian section three miles northwest of Waynesboro, and possibly also by the more siliceous base of the Silurian section at the Maddox mill. Finally, the Osgood bed at Riverside is overlaid apparently unconformably by the Laurel, and south of Riverside and Clifton is either represented a much diminished section, not more than 3 feet thick, or cannot be differentiated as a distinct formation.

The identification of the Warren bed rests chiefly upon the presence of *Dinorthis retrorsa*. A variety of this fossil has recently been found in the upper third of the Lower Richmond or Waynesville bed, in Indiana, but it has fewer, coarser, and more distant radiating plications than the Warren bed form. However, the identification of a horizon should rest, not upon a single species,

[1] JOHN M. NICKLES, "Geology of Cincinnati," *Journal of Cincinnati Society of Natural History*, Vol. XX (1902), No. 2.

but upon the entire fauna. This will require further collecting. I desire here merely to call attention to the fact that even within the limited exposure at Clifton the supposed Warren bed runs out southward, and that this exposure also presents the thickest Richmond section so far discovered along the Tennessee River.

Recently Mr. Ray S. Bassler has identified *Hemiphragma imperfectum*, a characteristic species of the Upper Richmond in Illinois, from the coarse, cross-bedded ferruginous rock at the base of the Silurian section at Iron City. This necessitates also the reference of the cross-bedded, less ferruginous rock at the base of the Silurian section at Riverside to the Upper Richmond, the Clinton at both localities consisting of less than 1 foot of silicious or cherty limestone. The coarse conglomerate, half a mile east of Cedar Point at Iron City, is also probably of Upper Richmond age. While these rocks suggest deposition in shallow waters, and the probable vicinity of shore lines, their relation to a probable mass of elevated land toward the westward is unknown. The relation of this problematical mass of elevated land to the Nashville dome, as the southern half of the Cincinnati geanticline is sometimes called, also remains in doubt.

16. *As determined by observations in Ohio, Indiana, and Kentucky.* — In Ohio, Indiana, and Kentucky no unconformity has been noticed between any of the subdivisions of the Niagaran. The *Cayugan* is represented by a series of strata not sufficiently studied as yet to be divided into horizons. The *Salina* division is represented by the *Eurypterus* bearing beds at Kokomo, Indiana. In New York and adjacent Ontario these beds have been called the *Bertie or Lower Waterlime*. The *Manlius* division of the Cayugan is represented in part by the hydraulic limestone at Belleville, Sandusky county, Ohio, and the *Greenfield* limestone in the southern part of the state, as far as may be determined by the presence of *Orthothetes interstriatus* (*O. hydraulicus*), a fossil characteristic of the lowest or *Cobleskill* subdivision of the Manlius in New York, Pennsylvania, and Maryland. *Spirifer vanuxemi*, found on Put-in-Bay Island, Lake Erie, and *Leperditia alta*, identified at Bellevue, Sandusky county, Ohio, are characteristic of the *Manlius proper*, the upper member of the Manlius

division of the Cayugan of New York. Very little is known of the Cayugan in Ohio or Indiana beyond the fact that it is much thicker in the northern parts of these states and thins out southwards. It has not been detected south of the central part of Indiana, but in Ohio it it has been followed beyond Greenfield to the southern boundary of the state. It appears to cross the Ohio River into the northern part of the state of Kentucky. Recent observations suggest that the Cayugan (Greenfield or possibly Monroe) limestone of southern Ohio and northern Kentucky is unconformable to the Niagaran.

The Paleodevonic has not been recognized in Ohio, Indiana, or Kentucky. Various sandy beds have at different times been referred to the Oriskany, upon lithological rather than upon paleontological data.

The base of Mesodevonic is represented in central Indiana by the *Pendleton sandstone*, referred by Hall to the *Schoharie Grit*. The *Corniferous* or *Onondaga limestone* extends to the central part of the state of Kentucky, on both sides of the Cincinnati geanticline.[1] Indeed, in central Kentucky, the Corniferous is exposed at various points along the crest of the geanticline. East of the geanticline it extends as far south as the lower parts of Fishing Creek, west of Somerset. In Indiana and western Kentucky, the *Hamilton*, represented by the *Sellersburg* bed, is not known south of Louisville. In Ohio, on the eastern side of the geanticline, the Sandusky or Delaware limestone has been identified as the lower part of the Erian, and the Olentangy shales as the upper or Hamilton part. Neither of these beds has been identified south of the central part of the state. It does not reach the Ohio River, and certainly has not been seen in Kentucky.

There is no doubt about the presence of the Cincinnati geanticline in central Kentucky and in the neighboring parts of Indiana and Ohio, in times preceding the deposition of the Corniferous. The unconformity between the Corniferous and the various Niagaran and Ordovician strata is often very striking, con-

[1] CHARLES SCHUCHERT, "On the Faunal Provinces of the Middle Devonic of America." *Am. Geol.*, Vol. 32 (1903), No. 3.

sidering the comparatively small dips characterizing the strata along the Cincinnati geanticline. The absence of the entire Paleodevonic suggests the existence of a long period of no deposition between the Corniferous and Cayugan. During this time there may have been considerable erosion. Recent observations in southern Ohio and northern Kentucky, east of the geanticline, indicate the existence of a considerable unconformity between the Cayugan and the various subdivisions of the Niagaran. This suggests the origin of the northern part of the Cincinnati geanticline in times preceding the Cayugan. Observations are not yet sufficiently extended to lead to a definite conclusion.

There are indications of a rise of the sea bottom southward in Kentucky during the latter part of the Ordovician, accompanied by a slow sinking of sea bottom northward in Ohio and Indiana, but it has not yet been determined that these changes produced folding parallel to the Cincinnati geanticline. The absence of the entire Utica, of most of the upper Lorraine, and of all except the upper part of the Richmond, in Tennessee, suggests a relation between the facts observed in Kentucky and those discovered in Tennessee. The rise of the sea bottom appears to have begun much earlier in Tennessee than in central Kentucky, and to have been more pronounced in central Kentucky than in southern Ohio. It has, however, not been shown as yet that this elevation was more pronounced along the crest of the Cincinnati geanticline than on its flanks. The emphasis given to this lack of stratigraphic evidence at present may lead to future observations which may corroborate the deductions as to the very early origin of the geanticline, perhaps even in Ordovician times, based on paleontological data.

LOCALITIES MENTIONED IN THIS PAPER.

(Consult map on p. 30 of this volume.)

1. Paulk or Watson mill.
1*a*. Cave half a mile north of 1.
2. Junction of Turkey and Horse Creeks, a quarter of a mile above 1.
3. Iron bridge.
4. Lick Ford, at mouth of Willoughby Creek.

5. Willoughby Creek, above the mouth.
6. Welch or Maddox mill.
7. Dodds' mill.
8. Sulphur Spring, Ross and Arnold farms.
9. Calybeate Spring.
9*a*. Two hundred yards north of Calybeate Spring, north of mouth of branch.
10. Cab Blount.
10*a*. Pyburn Bluff, a mile and a half northeast of White Sulphur Spring.
10*b*. West slope of hill at store, White Sulphur Spring.
11. Cave Spring southeast of Cerro Gordo.
12. Cerro Gordo.
13. Saltillo.
14. Exposures along landing at Clifton.
14*a*. Hillside north of Waynesboro road, at eastern edge of Clifton.
14*b*. West of Eagle Creek, 3 miles from Clifton on road to Martin's mill.
14*c*. Three-quarters of a mile above the landing at Clifton.
14*d*. Swallow Bluff, on north side of river, half-way between mouths of Indian and Hardin Creeks.
14*e*. Bath Springs.
15. North of landing at Glenkirk, at mouth of Beech Creek; marked Dunkirk on the map.
15*a*. Short Creek, northeast of Lego, 300 yards southeast of W. E. Ashley and P. Denman.
15*b*. Along road leading east from New Era.
16. Glade southwest of Brownsport Furnace, 3 miles west of Vice Landing.
17. Glade northwest of Charles McClanahan's home, 2 miles west of Vice store.
18. Mound glade, ¼ mile north of Vice store, on Perryville road.
19. Mound glade, ½ mile west of 18.
19*a*. Series of glades southwest of Dixon Spring.
20. Northwest edge of Perryville.
21. Quarry northeast of Perryville, on Tennessee River.
22. William H. Patten, one mile north of Linden, at spring north of house.
22*a*. Exposure in woods at bluff northeast of 22.
23. East of William Goodwin, Coon Creek, 2.2 miles east of Linden.
24. Spring northeast of J. M. Goodwin, farther up Coon Creek.
25. Spring, eastern edge of Linden.
26. Quarter of a mile west of J. S. Journey, Short Creek, 1 mile east of Linden.
27. E. Duncan, 1.5 miles east of Linden, at mouth of Jacks branch of Short Creek.
28. Webb or Rise mill.
28*a*. Tate hollow, half a mile from Buffalo River, at forks of road, 3 miles south of Linden.

29. North of railroad bridge, northwest of Riverside.
29*a*. At station, Iron City.
29*b*. At Cedar Point, a mile north of station at Iron City, on west side of railroad to Pinckney.
30. Northeast of mouth of Trace Creek, west of Riverside.
31. Bluff on Buffalo River, east of Ezekial Cothran, 2 miles southwest of 30.
32. South of Ed. Walker, east side of Tucker Branch.
33. Road crossing over Carter Creek.
34. South of Old Mill on Mill Creek.
35. Between Big Opossum and Hope Creeks.
36. Half a mile west of Dr. Evans, west of Hope Creek.
37. Northwest of Flat Woods, at mouth of Little Opossum Creek.
38. John Henry Johnson, along Waynesboro road, 7 miles east of Savannah.
39. East of George Wilson, 7.5 miles east of Savannah.
39*a*. East of Jim Irwin, 8 miles east of Savannah.
40. Old Colonel Jim Smith place, 9 miles east of Savannah; John Goodwin farm, 4 miles east of Economy.
41. Southeast of W. D. Helton on Beech Creek, 3.5 miles northwest of Waynesboro.
42. Six miles west of Waynesboro, at crossing of Martin's mill road over Brewer Branch.
43. West of Dr. Yeiser, 6 miles east of Martin's mill.
44. Hillside northeast of stables on Gant Place.
45. Half a mile north of Martin's mill on north side of Indian Creek, opposite site of Craven's mill.
46. Hillside at north end of Martin's mill.
47. A mile and a half northwest of Martin's mill, on north side of Indian Creek.
48. Half a mile west of 47, where road ascends the hill.
49. Four miles northwest of Martin's mill, on south side of Indian Creek, south of the home of Mr. Phillips.
100. Whirl of Buffalo River, 5 miles by road north of Bakerviile.
101. Along railroad, northwest of John Broadus.
102. Hillside east of John Broadus.
103. Northwest of Dr. W. B. Scott.
104. Half a mile west of Cumberland City, along the river.
105. Christopher Schmidt, hill slope south of house, about 2 miles west of John Broadus.

WELLS (UPPER STONES RIVER) FOSSILS.

The fossils here listed were obtained about a mile and a quarter southwest of Cumberland City, along the railroad, about half a mile south of the crossing of the Erin pike:

Illaenus; glabellae slightly resembling *I. americanus*, but not accompanied by the characteristic pygidia of that species; probably identical with the forms listed by Safford from the Glade limestone as I. americanus.

Maclurea bigsbyi.

Crania; related to *setigera*, but with the surface of the upper valve crowded with minute pustules which may have been the bases of setae.

Orthis tricenaria.

Dinorthis deflecta.

Dalmanella subaequata, variety.

Strophomena incurvata (*filitexta*).

Rafinesquina minnesotensis (*incrassata* of Safford).

Plectambonites sericea.

Hallina nicolleti?

Zygospira recurvirostris.

Rhynchotrema related to *inaequivalvis*, but with a more triangular outline, and with the sides more flattened, producing a more angular shell; probably identical with *Rh. orientalis* of Safford.

Helopora spiniformis, identified by R. S. Bassler.

SALTILLO (LOWER TRENTON) FOSSILS.

Whiteavesia, identified by R. S. Bassler as identical with a species found in the Lower Trenton in Central Tennessee; W. D. Helton locality.

Leptobolus, resembling *insignis*, Clifton.

Trematis punctistriata, Clifton.

Schizocrania (?) *rudis*, Clifton.

Schizocrania, related to *filosa*, Clifton.

Lingula, Clifton.

Dalmanella, apparently an ancestral form of *D. emacerata* from the Utica group of the Cincinnati region; some of the specimens are 18 mm long and 28 mm wide, but usually the dimensions are 16 by 21. When compared with Utica specimens which have not been crushed flat, the similarity is striking. W. D. Helton, Clifton, Wells creek basin.

Zygospira modesta, with the four median plications of the ventral valve forming a distinct fold, the slightly more distinct median groove separating these plications into pairs; Clifton.

CLINTON FOSSILS.

Illaenus daytonensis, glabellae and *pygidia*; 14, 15, 29*b*.

Illaenus, pygidia resembling *madisonianus*, but with a less triangular outline; found in Clinton of Ohio and Indiana, 14*d*, 29.

Calymmene vogdesi, pygidia and *glabellae*; 14, 14*d*.

Lichas breviceps clintonensis, glabellae and pygidia; 14.

Cyrtoceras (*Glyptoceras*) *subcompressum*, showing surface marking and siphuncle; 14.

Orthoceras ignotum, showing smooth surface; 14.

Cyclonema daytonensis (published as *C. bilix* in Vol. VII, *Ohio Survey*, Pl. 30, Fig. 15; see also *Twenty-fourth Annual Report of Indiana Survey for 1899*, p. 77); 14.

Diaphorostoma (*Platyostoma*) *niagarense*; 14.

Cypricardinia related to *undulostriata*, found also in Ohio (*Ohio Survey*, Vol. VII, Pl. 47, Fig. 9); 14.

Orthis flabellites; 14.

Platystrophia daytonensis; 14.

Dalmanella elegantula; 14, 14*d*.

Triplecia ortoni; 14, 29*b*.

Leptaena rhomboidalis; 14, 14*d*, 29*b*.

Plectambonites transversalis elegantula; 14.

Stricklandinia (*?*) *dichotoma*; generic affinities uncertain, the interior being unknown; valve moderately convex, 23^{mm} long, 30^{mm} wide, marked by about 20 plications on the posterior half of the shell, of which all except the posterolateral ones branch once dichotomously on the interior half of the shell, crossed by very fine concentric striæ; 14, 29, 29*b*.

Pentameroid shell of unknown generic affinities; valves nearly equal, the beak of the ventral valve extending slightly beyond that of the dorsal valve; the interior of the ventral valve apparently supplied with a short septum supporting a very small spondylium; the interior of the dorsal valve does not show two parallel septa; form oblong; length 35^{mm}; width 28^{mm}; thickness 16^{mm}; valves with low, broad, radiating plications which increase in number anteriorly both by dichotomous branching and by intercalation, those along the center of the valve often raised on an almost imperceptible fold; 29, 29*b*.

Atrypa marginalis; 14*d*.

Favosites favosus; 14, 29.

Favosites niagarensis; 14.

Halysites catenulatus; 14, 29.

WALDRON FOSSILS.

Hyolithes newsomensis; length 25^{mm}, the convex side sharply striated longitudinally, the more prominent striæ being separated by 4 to 8 finer ones; the flat side nearly smooth; 14*d*, 29*a*.

Orthoceras amycus; 14*c*, 14*d*, 29*a*, 29*b*.

Orthoceras simulator; 14*c*, 14*d*.

Diaphorostoma niagarense; 15*b*, 29*a*.

Cypricardinia arata; 14*d*, 15*b*.

Dictyonolla reticulata; 14*d*, 15*b*.

Meristina maria; 14*c*, 14*d*, 15*b*, 29*b*.

Homoeospira evax; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*.

Homoeospira sebrina; 29*a*.

Homoeospira, more convex than *sobrina*; found also at Newsom, 29*a*.
Whitfieldella nitida; minute, 15*b*.
Nucleospira pisiformis; 14*d*, 15*b*, 29*a*, 29*b*.
Spirifer swallowensis; resembling *crispatus*, but with only one well developed lateral fold on each side; 14*d*.
Spirifer eudora; 29*b*.
Reticularia petila; 14*d*, 15*b*.
Atrypa reticularis newsomensis; 14*d*, 15*b*, 29*a*, 29*b*.
Atrypina disparilis; 14*d*, 29*a*, 29*b*.
Anastrophia internascens; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*.
Plectambonites tennesseensis; width 7–9^{mm}; convex valve with about 5 striæ, which are conspicuously stronger than the remainder, partly due to radiate plication; form as in *transversalis*; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*; found also at Newsom.
Leptaena rhomboidalis; 14*c*, 14*d*.
Rhipidomella hybrida; 14*c*, 14*d*, 15*b*, 29*a*.
Dalmanella elegantula; 14*d*, 29*a*, 29*b*.
Macrostylocrinus striatus; 29*a*.
Lecanocrinus pusillus; 29*a*.
Eucalyptocrinus magnus; 14*c*.
Eucalyptocrinus elrodi; 14*c*.
Stephanocrinus gemmiformis; 14*c*, 14*d*, 29*a*, 29*b*.
Stephanocrinis tennesseensis; body approximately inversely conical, the sides diverging at angles varying from 50 to 60 degrees; constriction at base usually slight; base usually sharply pointed and triangular in cross-section; some specimens less acute, much larger than *gemmiformis* from the same beds; length to base of ambulacral grooves 6.5 to 7.5^{mm}, length of interambulacral projections of the body 2^{mm}; 14*c*, 14*d*, 15*b*, 29*a*.
Callopora elegantula; 14*d*, 29*a*.
Streptolasma radicans; 29*a*.
Astylospongia praemorsa pusilla; 14*d*.

BROWNSPORT FOSSILS.

Acidaspis, 1 species; spiny pygidium only; 46.
Calymmene niagarensis; 14*a*, 16. Gant bed at 46, Pegram, 14*eC*.
Ceraurus niagarensis; was found by Roemer in vicinity of Dixon Spring.
Dalmanites, 1 species; large, related to *D. verrucosus*; head 15, pygidium 16.
Encrinurus, 1 species; small pygidia; 14*a*, 35 Pegram.
Illaenus, 1 species; pygidia broad as in *I. armatus*; 14*a*, 15, 19*a*.
Phacops, 1 species; Gant bed 46.
Sphaerexochus romingeri; glabellae; 14*a*, 15, 14*eA*.
Amphicoelia ?, 1 species; large; 10 radiating plications in a width of 10^{mm}, 6^{cm} from the beak; 21.

Cypricardinia, 1 species; Gant bed 46.

Cypricardinia?, 1 species; small, related to *C. Caswelli*; 18.

Pterinea, 1 species; 16.

Cyclonema tennesseensis; not identified; type specimens found within several miles of Dixon Spring; 19*a*.

Holopea, 1 species; cast, 46.

Platyceras niagarense; 14*a*, 19*a*, 49.

Platyceras, brownsportensis vertically compressed at margin, more than in *Pl. sinuatum*; 12, 16, 14*eC*.

Diaphorostoma (*Platyostoma*) *niagarense*; 14*a*, 15, 16, 19*a*, 46, 49, 14*eA*, 14*eC*, 40.

Platyostoma, 1 species; general aspect that of a *Cyclonema*; 12, 16, 18.

Dictyonella gibbosa; Gant bed, 44, 46, 47; described by Hall from Perry county.

Dictyonella concinna; described by Hall from Perry county.

Dioryonella reticulata, 40.

Meristina maria roemeri; 15, 16, 19, 46, Pegram, 40.

Merista tennesseensis; 12, 16, 19, Gant bed 46, 14*eA*, 14*eC*, 39, 40.

Trematospira simplex; largest specimens 18^{mm} long; common at 12, 16, 14*eC*, 40.

Trematospira, 1 species; 6^{mm} long, with general outline and form of *T. tennesseensis*, but much smaller; Gant bed 44.

Homoeospira schucherti; largest specimen 13^{mm} in length, both valves with narrow median depression occupied by 1 or 2 narrow plications; type from Brownsport, 12, top 16, 18, 19, 44, 46, 47, 14*eA*, 14*eC*, 39, 40.

Homoeospira sobrina (?); 14*eC*, 38, 40.

Homoeospira beecheri; largest specimen 8^{mm} in length; shallow depression of ventral valve occupied by 2 plications slightly smaller than the rest; bottom of median furrow of dorsal valve occupied anteriorly by 2 narrow striæ, which are the bifurcated top of a low plication easily overlooked; type from Brownsport, 16.

Anoplotheca (*Coelospira*) *saffordi*; length 5^{mm}; ventral valve strongly convex, with 3 plications forming an indistinct median elevation, and with 3 distinct and 1 or 2 indistinct plications on each side; dorsal valve concave, especially anteriorly along the shallow median depression; depression occupied by 2 plications close together, more widely separated from the neighboring plications; Gant bed at 44, 14*eC*, 39.

Nucleospira concentrica; Gant bed, 44, 47; type from Decatur county, quoted by Whitfield and Hovey from Meniscus beds of Decatur county, and by Safford from Bath Springs in Decatur county; 14*eA*, 14*eC*, 39, 40.

Nucleospira, 1 species; probably *pisiformis*; 14, Gant bed 44, 14*eA*.

Cyrtia cliftonensis; height of cardinal area 6^{mm}, width 10^{mm}; margins of sinus of ventral valve distinct and angular, diverging at an angle of 52°, resembling *C. meta*; 14*a*.

Reticularia pegramensis; length 15mm, width 19mm; median fold low, but distinct, 5mm broad anteriorly; median depression shallow; no lateral plications; concentric lines of growth distinct; found only at Pegram.

Delthyris, 1 species; 8mm long, 10.5mm wide; median plication of dorsal valve with faint depression along the axis anteriorly; 3 distinct and 1 indistinct plication on each side; cardinal angles acute; surface ornamentation similar to that of *Spirifer crispus*; 12, 16.

Spirifer oligoptychus; the radiating striæ are coarser than in *Sp. eudora* from the Waldron bed, and are not crenulated by transverse lines of growth, 14*a*, 19*a*.

Spirifer geronticus; 20mm long; median fold and sinus distinct; 1 or 2 on each side at the beak, usually disappearing within 7mm from the beak; radiating striæ; type from Dixon Spring; 14*a*, 19*a*, 49, Pegram.

Spirifer foggi; 14*a*, 19*a*, Pegram.

Spirifer saffordi; surface ornamented as in *Sp. crispus*, but the concentric striæ are much more distinct; cited by Whitfield and Hovey from the Meniscus beds of Perry county, Tenn., and by Safford from the Gant locality in Wayne county, and Bath Springs in Decatur county, formerly a part of Perry county, Gant bed 44.

Spirifer crispus; 12, 16, 19*a*, 40.

Spirifer crispus variety; concentric striæ finer and closer together; shell slightly narrower; 12, 16, 14*eC*.

Atrypa reticularis newsomensis; types from Waldron bed at Newsom, Tenn., 8 or 9 plications in a width of 10mm; 16, 19, Pegram, 14*eC*, 39, 40.

Atrypa reticularis niagarensis; 12 to 14 plications in a width of 10mm; 14*a*, 16, 19, 19*a*, 49, 103, Pegram, 14*eA*.

Atrypa reticularis arctostriatus; 28 plications in a width of 10mm; top at 16.

Atrypa marginalis; 14*a*, 15, 16, 18, 19*a*, 49; similar forms included by Nettelroth under *C. Calvini*; 14*eA*.

Atrypina, 1 species; 16, 19*a*, 21.

Uncinulus stricklandi; 12, 16, 21, 43, 46, Gant bed 45, 46, 14*eC*, 40, 15*a*.

Uncinulus tennesseensis; shell smaller than *stricklandi*, usually with fold and sinus more distinct; 12, 14*a*, 16, 19, 19*a*, 20, Gant bed 46, Pegram, 14*eC*, 40.

Rhynchonella lindenensis; outline roughly circular; with three plications on fold, 2 in sinus, and 8 or 9 on each side; at 27 near Linden. A similar shell with only 6 or 7 plications on each side occurs at 16 near Brownsport Furnace; interiors unknown.

Wilsonia saffordi; 14*a*, 15, 16, 19, 19*a*, 49, 103, Gant bed 44, 46, 14*eA*, 14*eC*, 39, 40.

Camarotoechia; similar in form to *C. neglecta*, but 12mm long and with the surface apparently smooth; 12, 16, 19, 19*a*, 27, Gant bed 46, 14*eC*, 38, 40.

Camarotoechia; cuneate in form, 11mm long; sinus and fold almost imperceptible except on direct anterior face of shell; 12, 16.

Gypidula roemeri; 14*a*, 16, 18, 34, Gant bed 46, 14*eC*, 39, 40, 15*a*.

Conchidium littoni; described from Hardin county; identified by Safford from the Meniscus horizon.

Conchidium legoensis; length, 29 to 31^{mm}; width, 20 to 24^{mm}; thickness, 16 to 17^{mm}; 12 to 14 radiating plications; related to *C. crassiplica*; 15*a*.

Conchidium lindenensis; in form and frequency of radiating plications most nearly resembling *C. colleti*, but without frequent lines of growth, and only 50^{mm} long; not rare within 10 feet of base of section, east of house of William Goodwin on Coon Creek, opposite road leading off to Linden; 23.

Plectambonites, 1 species; Gant bed 44.

Strophonella roemeri; profile resembling Fig. 4*c*, Plate 23, Vol. III, *N. Y. Pal.*; striæ very fine and numerous in umbonal region, every fifth or sixth one distinctly more prominent; the more prominent striæ become more numerous in the pallial region, 12 to 15 in a width of 10^{mm}; length 43^{mm}, width 60^{mm}, outline triangular; about 35 feet above base of Dixon bed at Brownsport Furnace, 16; Gant bed 46; 12, New Era.

Strophonella prolongata; width 31^{mm}, length 15^{mm}; plications 18 to 21 in a width of 10^{mm} along anterior margin, numerous at beak; profile as in Fig. 6*c*, Plate 23, Vol. III, *N. Y. Pal.*; 16, 19*a*, Gant bed 44, 46, 39.

Strophonella laxiplicatus; plications consist of sharp narrow ridges separated by comparatively wide spaces, new plications are added along the middle of these spaces. Comparatively few plications (usually less than 10) begin at the beak. Related to *Str. semifasciata*, but plications more numerous, more prominent, and shell much smaller; 16, 12, 14*eC*, 39.

Leptaena rhomboidalis; 16, 14*a*, Gant bed, 46, 14*eC*, 39.

Orthothetes subplanus; 12, 16, 14*eA*, 14*eC*, 40.

Orthothetes roemeri; plications fewer, separated by wider spaces; shell much smaller; 19*a*, Pegram.

Dalmanella fissiplica; 19*a*, 14*a*, 36, 49, 103, 14*eA*.

Dalmanella elegantula; only 11^{mm} long, otherwise typical; 14*a*, 19*a*, 35. Larger form with usually finer striae, 20^{mm} long; top at 16, 14*eC*, 39, 40.

Dalmanella arcuaria; 14*a*, 15, 16, 18, 46, 49, 103.

Rhipidomella lenticularis; resembles *Rh. circulus*, but the striæ are much more numerous, largest specimens 28^{mm} long; top at 16.

Rhipidomella hybrida; variety, 12^{mm} long; 14*eC*, 38, 39, 40.

Rhipidomella saffordi; length 8^{mm}, dorsal valve strongly convex, but indented along the middle by a distinct depression which begins at the beak and is widest and deepest at the anterior margin; Gant bed 44, Pegram, 14*eC*, 39.

Bilobites biloba; 14*a*, 19*a*.

Allocrinus typus; Clifton and Decatur counties.

Callicrinus (*Eucalyptocrinus*) *ramifer*; Wayne and Decatur counties.

Caryocrinus ornatus; 14*a*, 16, 19*a*, 49.

Caryocrinus bulbulus; Wayne county.
Caryocrinus milliganae; Decatur county.
Centrocrinus tennesseensis; Clifton.
Coccocrinus bacca; 49.
Cystocrinus tennesseensis; a parasitic growth on a crinoid stem; 14*a*, 19*a*, 20.
Eucalyptocrinus ventricosus (= *E. caelatus* of Roemer); Decatur, Wayne and Perry counties; 14*eA*.
Eucalyptocrinus milliganae; Decatur county.
Eucalyptocrinus lindahli (= *wortheni* of Miller); Wayne county.
Gazacrinus tennesseensis; Tennessee, locality unknown.
Glyptaster milliganae; Decatur county.
Idiocrinus tennesseensis; Clifton.
Lampterocrinus tennesseensis; 15, 19*a*, 20, 49.
Lecanocrinus pisiformis (*Poteriocrinus*); 19*a*, 18, 49, 46, 39.
Lecanocrinus. 1 species; identified by Springer as a form found at St. Paul Indiana; 21.
Lecanocrinus pusillus; 16.
Marsupiocrinus striatus; Decatur county.
Marsupiocrinus (*Platycrinus*) tennesseensis; 14*a*, 16, 19*a*, 49.
Melocrinus (*Mariacrinus*) *nobillisimus*; cited as occurring apparently in the Niagara of western Tennessee.
Melocrinus (*Cytocrinus*) *roemeri* (= *laevis*); 46. This may be *Actinocrinus verneuli* of Troost.
Myelodactytus gorbyi; cited from Tennessee.
Periechocrinus tennesseensis (= *Saccocrinus speciosus* of Roemer); 14*a*.
Pisocrinus campana; 15, 14*a*, 19*a*, 46, 49.
Pisocrinus gemmiformis; 14*a*, 19*a*, 35, 39.
Pisocrinus milligani (= *gorbyi*); 14*a*, 15, 19*a*, 46, 49, 38.
Pisocrinus (*Synbathocrinus*) *tennesseensis*; 14*a*, 19*a*, 49.
Taxocrinus; genus identified by Springer, 14*a*.
Thalamocrinus ovatus; Decatur county.
Thalamocrinus cylindricus; Decatur county.
Thysanocrinus milliganae; Decatur county.
Troostocrinus (*Pentatrematites*) *reinwardti*; 15, 16, 18, 19*a*, 49, 14*eA*.
Zophocrinus howardi; 14*a*.
Callopora elegantula; 16, 19, 12, 14*eC*, 39, 40.
Fistulipora (*Thecostegites*) *hemispherica*; 14*a*, 16, 32, 34, 35, 42, in Brownsport bed; abundant also in Dixon bed, 14*eA*, 14*eC*, 14*eE*, 39.
Alveolites niagarensis; 27.
Amplexus shumardi; 14*a*, 16, 27, 46, 38, 39*a*.
Anisophyllum; listed as An. agassizi by Prof. Safford, 14*eC*, 39.
Aulopora roemeri (= *repens* of Roemer); 27.
Calceola tennesseensis; 14*a*, 15, 16, 27, Pegram.
Cladopora complanata; 27.

Cladopora reticulata; 27.

Coenites verticillata; 27.

Ditoecholasma (Petraia) fanningana; 14*a*, 15, 16, 19*a*, 49, 14*eC*, 39*a*.

Enterolasma (Petraia) waynense; 14*a*, 16, 19*a*, 46, 49, 36, 14*eA*, 14*eC*, 14*eE*.

Eridophyllum proliferum; related to *E. sentum*, but corallites free, not connected laterally; the calyx of mature specimens not often seen, because usually filled by young corallets, invariably 4 corallets in each calyx; 16, 27, 39*a*.

Favosites cristatus; 14*a*, 15, 16, 27, 46, 14*eC*, 40.

Favosites cristatus major; 14*a*, 27, 46, 49.

Favosites discoidea; 14*a*, 16, 19*a* 32, 35, 49, Pegram, 14*eC*.

Favosites discus; 27, top of 16.

Favosites favosus; 16, 15, Pegram.

Favosites niagarensis; 27, 39*a*.

Favosites spongilla; 16, 27.

Favosites obpyriformis; growth globose or inversely pear-shaped, 12^{cm} in height; corallites 3 to 4^{mm} in diameter; 17.

Halysites catenulatus; 27.

Heliolites subtubulatus; 27, 16, 103.

Omphyma verrucosa; 16.

Laccophyllum acuminatum; Perry county, 14*a*, 16, 39*a*.

Plasmopora follis; 16, 27, 103, 38, 39*a*.

Platyaxum platys; corallum forming flat, very thin (1 to 3^{mm}) fronds, which are irregularly lobate; corallites very oblique; apertures sinuate, central part elevated, the sides adnate to the frond; probably congeneric with Alveolites; 15 corallites in a with of 10^{mm}; 16, 27.

Striatopora; related to Str. *flexuosa*; 12, 14*a*, 19, 19*a*, 16.

Thecia major; 14*a*, 27, 39*a*

Thecia swindernana; 15, 16, 27.

Ptychophyllum vulcanius; coral 65^{mm} wide, thin at the edges, 4^{mm} thick 17^{mm} from the center, maximum height 15^{mm} at 6^{mm} from the center, about 10^{mm} at the center. Top of coral flat; the base is not preserved, but, judging from what remains, its sides once spread at an angle of more than 45°, until it reached a diameter of about 35^{mm}, and then it spread almost horizontally. A basal view suggests the appearance of a model of a low volcano, with a distinct crater at the center. The septæ from this side have a striking resemblance to those forming the calyx in *Ptychophyllum ipomoea*; 36.

Astracospongia meniscus; 14*a*, 14*b*, 22, 20, 35, 37, 43, 44, 46, 49, 102, 103, 14*eA*, 15*b*.

Anomoclomella zitteli; Decatur county.

Astylomanon cratera (Palaeomanon); figured by Roemer in his monograph of West Tennessee fossils on Plate 1; to Figs. 4 and 4*a* must be added also Figs. 1 and 1*a* on the same plate, according to Rauff. The following

varieties are established: *prototypum, aryballium, balantium, lecythium, promiscua, poterium, cantharium, cylix* which is the typical form, *patera*; 14*a*, 15, 19*a*, 28*a*, 103, 14*eA*.

Astylomanon pluriexcavatum; Decatur county.

Astylomanon verrucosum; figured by Roemer as *Astylospongia praemorsa* on Plate 1, Figs. 1*b*, 1*c*; 14*a*, 15, 16, 19*a*, 46, 103, Gant bed 46, 14*eA*, 39, 39*a*.

Astylomanon verrucosum bulbifera; Decatur county.

Carpomanon glandulosum; Decatur county.

Caryomanon roemeri; western Tennessee.

Caryomanon inciso-lobatum; 14*a*, 16, 46, 47, Gant bed 46, 14*eA*, 14*eC*.

Caryomanon stellatim-sulcatum; 14*a*, 15, 16, 19*a*, 22, 46, 49, 14*b*, 103, Gant bed 46, 14*eA*, 14*eE*, 38, 15*b*.

Caryomanon stellatim-sulcatum distorta; Decatur county.

Chiastoclonella headi; Decatur county.

Dendroclonella rugosa; Perry county.

Hindia sphaeroidalis (*Calamopora fibrosa* of Roemer); 14*a*, 15, 16, 27, 103, 14*eA*, 38.

Pycnopegma pileum; Decatur county.

Pycnopegma callosum; Decatur county.

Pycnopegma stromatoporoides; Decatur county.

Astylospongia imbricato-articulata; 14*a*, 15, 16, 46, 14*eA*.

LINDEN (HELDERBERGIAN) FOSSILS.

Favosites conicus; 10*a*, 10*b*, 21.

Favosites, with convex base covered by the epitheca; 9*a*, 10*a*, 10*b*, 21.

Pleurodictyum lenticulare; 10*a*, 10*b*, 21.

Striatopora issa; 21.

Brachiocrinus; 21.

Camarocrinus saffordi; 9*a*, 10*a*, 104.

Bilobites varica; 9*a*.

Dalmanites subcarinata, with coarse striæ; 9*a*, 10*b*, 21.

Dalmanites subcarinata, with fine striæ; 9*a*, 21.

Hebertella; 21.

Rhipidomella emarginata; 21.

Rhipidomella oblata; 9*a*, 10*a*, 10*b*, 21.

Orthothetes woolworthanus; 10*a*, 10*b*, 21, 22.

Leptaena rhomboidalis; 9*a*, 10*a*, 21.

Strophcodonta beckei; 10*a*, 10*b*, 21.

Strophonella punctulifera; 9*a*, 10*a*, 21, 104.

Chonostrophia, related to *Helderbergia*, but wider in proportion to length; 23^{mm} wide, 11^{mm} long; 10*a*.

Gypidula, without fold or sinus, plications narrow (as in Figs. 9–12, Plate 28, *The Paleozoic Fauna*, New Jersey Survey, 1903), but more obsolete towards beak and sides; 21, 104.

Uncinulus nucleolatus; 10*a*, 10*b*, 21, 104.

Uncinulus, with 2, occasionally with 4, plications on mesial fold, and 3 or 4 lateral plications; largest specimen 11^{mm} long, 11^{mm} wide, 10^{mm} thick, angular; 10*b*, 21.

Uncinulus, related to *vellicatus*, but smaller; the mesial fold only slightly elevated; ventral valve flattened toward the lateral margins and then abruptly bent toward the suture; 10*b*.

Uncinulus schucherti, resembling *Wilsonia saffordi*, but that part of the ventral valve occupying the fold projects far less beyond the lateral margins of the shell; the dorsal valve is more evenly convex; the anterior face of the shell is not flattened, so that a lateral view is less angular; plications on mesial fold vary from 4–5; of the lateral plications 7–10 are distinct, and 2–4 indistinct; largest specimen 15^{mm} long; globular or moderately elongated; 10*a*, 10*b*, 21.

Rhynchonella transversa; 10*b*, 21.

Rhynchonella bialveata; 21.

Rhynchotreta; cuneate triangular form without distinct sinus or fold; 21.

Atrypa reticularis; 10*a*, 10*b*, 21.

Cyrtina dalmani; 21.

Delthyris perlamellosus; 9*a*, 10*a*, 10*b*, 21, 22, 104.

Delthyris, related to *perlamellosus*, but with flat, high, triangular on ventral valve, giving the shell a slight resemblance to a *Cyrtina*; 10*a*, 10*b*, 21.

Spirifer cyclopterus; 10*a*, 10*b*, 22, 104.

Spirifer, with radiate striæ and 3 or 4 lateral plications; possibly identical with *Sp. tenuistriatus*, the horizon of that species not being definitely known; 10*a*.

Nucleospira; flatter than in *ventricosa*; 10*b*, 21.

Lissopleura; smooth, oblong, quadrangular form; 21.

Anoplotheca concava; 21.

Rhynchospira globosa; 10*b*, 21.

Rhynchospira formosa; 10*b*, 21, 22, 104.

Meristella Meeki; 10*a*, 10*b*, 21, 22, 104.

Meristella; related to *princeps*; 9*a*, 10*a*, 21, 104.

Platyceras tenuiliratum; 10*a*, 21.

Dalmanites pleuroptyx; 10*a*, 10*b*, 21.

Phacops logani; 10*a*.

AUG. F. FOERSTE.

DAYTON, O.

Reviews.

SUMMARIES OF THE LITERATURE OF ECONOMIC GEOLOGY.

I.

Edwin C. Eckel.

With the present issue the title of this section has been changed to conform to an enlargement in its scope. A brief outline of the plan which the writer purposes to follow may be of service to readers.

Papers and books relating to the economic geology of the United States will be summarized, so far as possible. Discussions of economic developments in foreign countries will be excluded, unless containing matter of general interest. Publications devoted largely or entirely to the technology of any mineral industry will not be summarized; but as such technologic papers appear to be of increasing interest to workers in economic geology, they will be listed by title, with occasionally a brief note to indicate their scope. Reports or papers containing statistical or compiled data only will be neither summarized nor listed.

The expansion of the scope of this series of summaries will necessitate the exclusion from it of many papers which would have been noticed under the old arrangement. The writer has planned, therefore, to continue the old series in *Municipal Engineering*, under the title "Recent Publications on Structural Materials."

Adams, G. T. "Principles Controlling the Geologic Deposition of the Hydrocarbons." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII; advance separate, 7 pp.

The author notes the present unsatisfactory condition of the literature on the hydrocarbons, in so far as their geologic interlation and the principles governing the origin of their economically valuable deposits are concerned; and applies to these problems certain principles allied to those stated by Van Hise for ore deposits. The principal difference, in this regard, between hydrocarbons and ores is that the latter are carried in solution, while the former are largely associated with the transporting water merely in a condition of mechanical mixture. The author then discusses the effect of the inferior specific gravity of the hydrocarbons, as compared with water; the different effects which will be produced, according as the hydrocarbon is merely miscible with, or soluble in, the transporting water; and the possibility that separations of the hydrocarbons, equivalent to those accomplished by fractional distillation, may be effected by differences in degrees of solubility, or in the character of the rock traversed.

BRANNER, J. C., AND NEWSOM, J. F. *The Phosphate Rocks of Arkansas.* Bull. 74, Arkansas Agric. Exp. Station. 8vo, 67 pp.

Three phosphate-bearing areas are noted in Arkansas. The first, and by far the most important, lies north of the Boston Mountains and west of Black River; the second, in the Cretaceous area of the southwestern part of the state; the third, north and west of Hot Springs. The second and third areas may be dismissed with the remark that little appears to be known concerning the phosphate beds they may contain.

The principal area is that in the northern part of the state. The phosphates here occur as nodules associated with the Sylamore sandstone and Eureka shale. These two formations together have a maximum thickness of 90 feet, and represent the Devonian of the region. The phosphates are therefore at the same horizon as the Tennessee black phosphates. Average specimens gave a phosphoric acid content equivalent to 30 per cent. to 70 per cent. calcium phosphate, with 4 per cent. to 20 per cent. iron and alumina. Unless better material is found, the rock will evidently be unable to compete, except locally, with Tennessee or other southern phosphates.

CROSBY, W. O. "Geological History of the Hematite Iron Ores of the Antwerp and Fowler Belt in New York." *American Geologist*, Vol. XXIX, pp. 233–42; also in *Technology Quarterly*, Vol. XIV, pp. 162–70.

The author discusses certain of the red hematite deposits of the western Adirondacks and concludes that the "ore body of the Sterling mine is in a dike, 50 feet or more in width, of some highly altered basic rock, possibly diabase; that the ore was originally a magmatic segregation of this rock, chiefly in the form of sulphides, which have subsequently suffered more or less complete oxidation to a considerable depth, the ore now being virtually a gossan; and that this dike is, probably, continuous for the entire length of the belt of mines, although absolute continuity is by no means essential to the hypothesis."

[It will be remembered that the "dike" in which the ore bodies occur is bordered by granite on the southeast, and by crystalline limestone on the northwest; and that Smyth has considered the chloritic "dike" rock to be merely a highly altered phase of the granite.]

DICKSON, C. W. "The Ore Deposits of Sudbury, Ontario." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII; advance separate, 65 pp.

The first part of this paper deals with "The Relation of Nickel to Pyrrhotite." The mineral associates, chemical composition, and nickel and cobalt content of pyrrhotites are discussed, particular attention being paid to the Sudbury and Algoma ores. The author states that "the nickel occurs in the pyrrhotite as the so-called pentlandite," but that, though "nearly all of the pentlandite can be separated from the pyrrotite by magnetic methods," "peculiar physical conditions seem to render its absolute elimination an impossibility." Magnetic separation is therefore a commercial impossibility. The further conclusion is reached that the Sudbury pyrrhotite conforms best to the formula Fe_nS_n.

The second part is entitled "Genesis of the Sudbury Ores," but contains in addition much material bearing on other districts. The Sudbury deposits and ores are discussed in detail, and the author concludes that the origin of the deposits is to be referred to replacement of the basic rock along crushed and faulted zones, and not to magmatic segregation. This conclusion is based upon the following line of argument:

Brecciation, with accompanying faulting and shearing, is noticeable both on a

large scale and in slides. Most of this took place prior to the formation of the ore deposits, and the ore prevailingly occurs as a cement for the brecciated rock-fragments and along shearing planes. All the rock is now more or less altered; and the more complete the alteration of the rock, the more complete has been its replacement by ore. Pyrrhotite occurs, it is true, as an original constituent of the norite, but the amount of this original pyrrhotite is very small. The abrupt change from massive sulphides to barren rock, the angular form of the included rock fragments, and the comparative freedom from sulphides of these fragments are further adduced in support of the theory that the ore deposits are essentially and predominantly secondary.

FLUKER, W. H. "Gold Mining in McDuffie County, Georgia." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII; also in *Eng. and Min. Jour.*, Vol. LXXIII, pp. 725, 726.

Of particular interest as describing a Georgia gold-mining district never before discussed in print, and far to the southeast of what is commonly considered the Georgia gold region. The veins carrying the auriferous pyrite are of the usual Appalachian type—stringers usually parallel to the lamination of the inclosing mica and hydromica schists.

HILL, B. F. *The Terlingua Quicksilver Deposits, Brewster County [Texas]*. Bull. 4, Univ. of Texas Mineral Survey. 8vo, pp. 74.

The rocks in the vicinity of the Brewster county quicksilver deposits are marine sediments representing the Lower and Upper Cretaceous and the Tertiary, with igneous rocks of late Tertiary age. The ores occur in the Cretaceous beds occupying fissures, either vertical or along bedding planes, marked by little or no displacement; and fault fissures marked by displacement with or without brecciated zones. Ore deposition in the district is supposed to have been due to the stimulus of the late Tertiary intrusions and flows. The common ores are cinnabar and native mercury, though other mercury ores occur in small quantity. The chief gangue material is calcite; aragonite and gypsum being next in importance.

MCCALLIE, S. W. "The Ducktown Copper Mining District." *Eng. and Min. Journ.*, Vol. LXXIV, pp. 439, 440.

Description of the geography, areal geology, and ore deposits of the Ducktown district of southeastern Tennessee and its extension into northern Georgia. The original contribution of greatest interest in this paper is the determination of the occurrence of sheared igneous rocks in the vicinity of the ore bodies, a dark gray quartz diorite occurring in linear areas parallel with the trend of the ore deposits.

PRATT, J. H. "Gold Mining in the Southern Appalachians." *Eng. and Min. Journ.*, Vol. LXXIV, pp. 241, 242.

Summary of recent gold-mining developments in Virginia, North Carolina, South Carolina, Alabama, and Tennessee.

SPURR, J. E. "The Original Source of the Lake Superior Iron Ores." *American Geologist*, Vol. XXIX, pp. 335–49.

The author points out that, though Van Hise and Leith agree with him in considering the original source of the Mesabi ores to be a green hydrous ferrous silicate of organic origin, they refuse to call this material glauconite, because of its low content or entire lack of potash. Spurr gives analyses and descriptions of undoubted glauconites from various localities, comparing these with the Mesabi material. He decides that, though the Mesabi silicate carries less potash (0.31 per cent. and 0.41 per cent.)

than any of the others, it is nearer the Australian (less than 1 per cent.), the Paris basin (1.70 per cent.) and the French Creek, Pa. (2.23 per cent.) glauconites than they are to the Grodno, Russia, material (7.57 per cent.). Recalling Murray and Renard's observation that the potash content of recent glauconites depends largely on the composition of the coastal rocks, he shows that the surface, at the time of deposition of the Mesabi iron-bearing formation, consisted of rocks very low in potash. His final conclusion, therefore, is that the Mesabi mineral is entitled to the name glauconite.

SPURR, J. E. "A Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII, advance separate, 53 pp.

The author discusses briefly the general relation of ore deposits to igneous rocks, pointing out that the ores were all originally derived from igneous rocks, and that most existing ore deposits are closely associated with areas or belts of such rocks. The sedimentary rocks, as a rule, contain a lower percentage of the metals than do rocks of igneous origin.

The differentiation of igneous rocks is then discussed, and the order in which the various minerals crystallize out of a molten magma is noted. The concentration of commercially valuable minerals by segregation within molten masses previous to their consolidation, is discussed in some detail, the metals being separately treated. The preference of concentrations of iron, chromium, nickel, copper, platinum (and probably cobalt) for the more basic igneous rocks, and that of molybdenum, tin, and tungsten for the acid rocks, is stated.

The author then takes up an original contribution to the study of ore deposits — the general preference of gold for the more siliceous igneous rocks, and the relationship of certain gold quartz veins to rocks of undoubted igneous origin. Studies in certain Alaskan and other districts have convinced him that many gold-quartz veins are to be regarded simply as extremely acid igneous rocks — the result of magmatic segregation — and correlative to the extremely basic rocks (pyroxenites, etc.) at the other end of the series. This theory is discussed in detail, and supporting observations, drawn from various districts, are given. This portion of the paper is summarized by the author in the statement that "although gold is present in all igneous rocks, and may be unequally distributed in any of them, yet the conditions for concentration by magmatic segregation become more favorable in proportion as the rock becomes more siliceous, and become *most* favorable in what has been shown to be the extreme siliceous product of rock-differentiation — in quartz-veins or dykes."

The merging of deposits formed by magmatic segregation into certain types of contact-deposits, and into deposits of gaseo-aqueous origin, is noted. The sequence of rock types in the volcanic eruptions of an area is then discussed, leading up to the relations between this sequence and the sequence of metalliferous deposits in the same area. The conclusion is then drawn that "by magmatic segregation the metals of commercial value, as well as the commoner rock-forming elements, are irregularly and to a certain extent independently concentrated in certain portions of the earth's crust. Such portions, characterized by the relative abundance of certain metals, may be called metalliferous provinces." These "metalliferous provinces" may be more or less closely identified with the different "petrographic provinces."

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—MANSON, MARSDEN. The Evolution of Climates. [Revised and reprinted from Amer. Geol., July, 1903.]

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